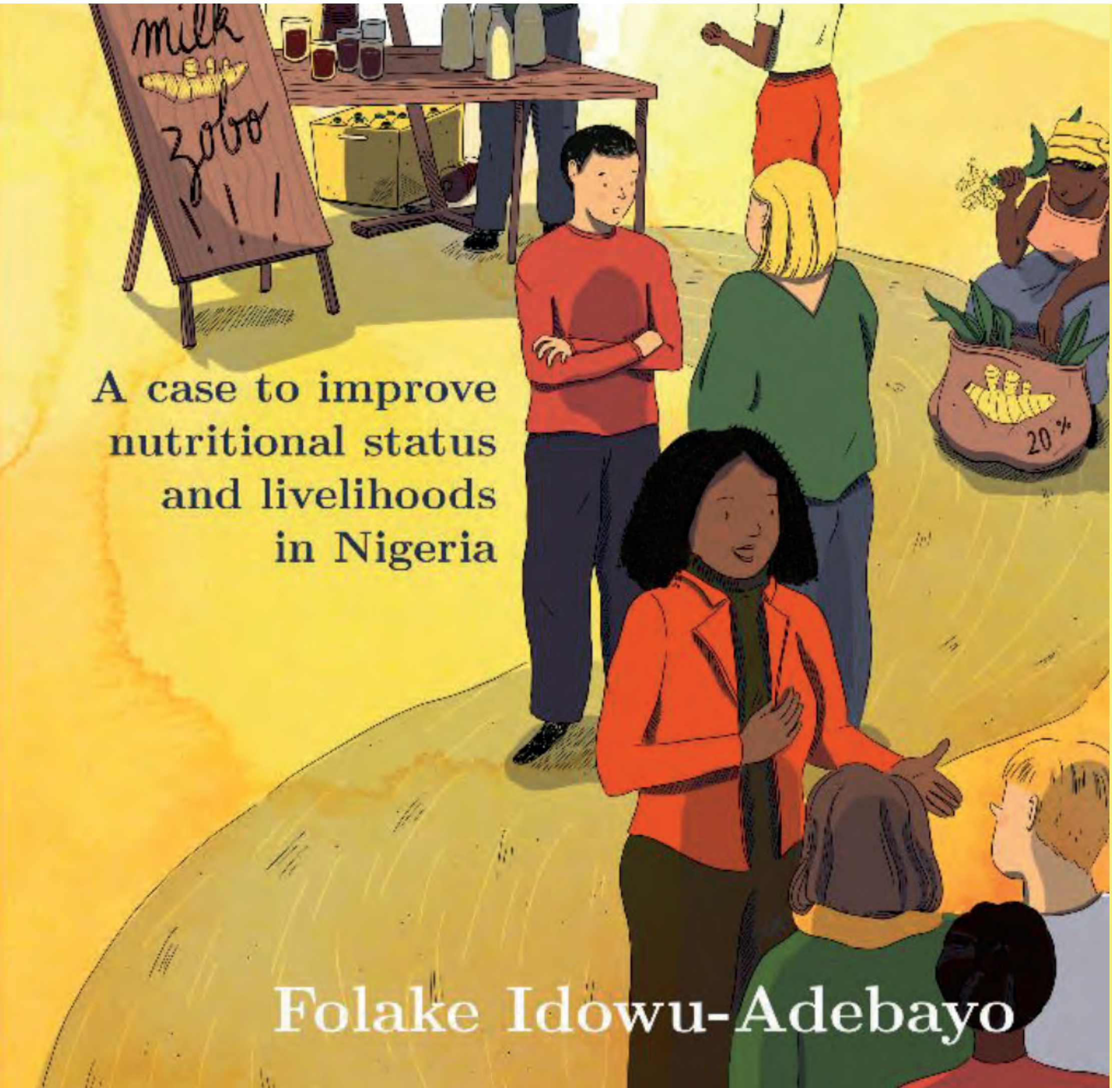
A case to improve nutritional status and livelihoods in Nigeria



Folake Idowu-Adebayo

Propositions

1. The major advantage of using local resources in food-to-food fortification is that the crops are widely available.
   (this thesis)
2. The Food Attitude Survey (FAS) method provides useful suggestions regarding individual differences in food liking and attitudes towards fortified foods.
   (this thesis)
3. Climate change awareness is a smart way to promote a healthy diet.
4. Bitter leaf (*Vernonia amygdalina*) is the sweetest vegetable.
5. The average Dutch person is a food quality and design expert.
6. A person in Africa who can feed a pet a healthy diet is not poor.
7. A place where police respond to a call to free a dog is a secure nation.

Propositions belonging to the thesis, entitled:

"Adoption of turmeric in street-vended beverages: a *case to improve nutritional status and livelihoods in Nigeria*."

Folake Idowu-Adebayo
Wageningen, 7th September 2022

Adoption of turmeric in street-vended beverages:

a case to improve nutritional status and livelihoods in Nigeria

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Adoption of turmeric in street-vended beverages:

a case to improve nutritional status and livelihoods in Nigeria

Folake Idowu-Adebayo

Thesis

submitted in fulfilment of the requirements for the degree of doctor
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Prof. Dr A.P.J. Mol,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
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To Osinachi Nwachukwu,

&

those who lost their lives in domestic violence

... Survivors would take the role of influencers to end all forms of domestic violence.

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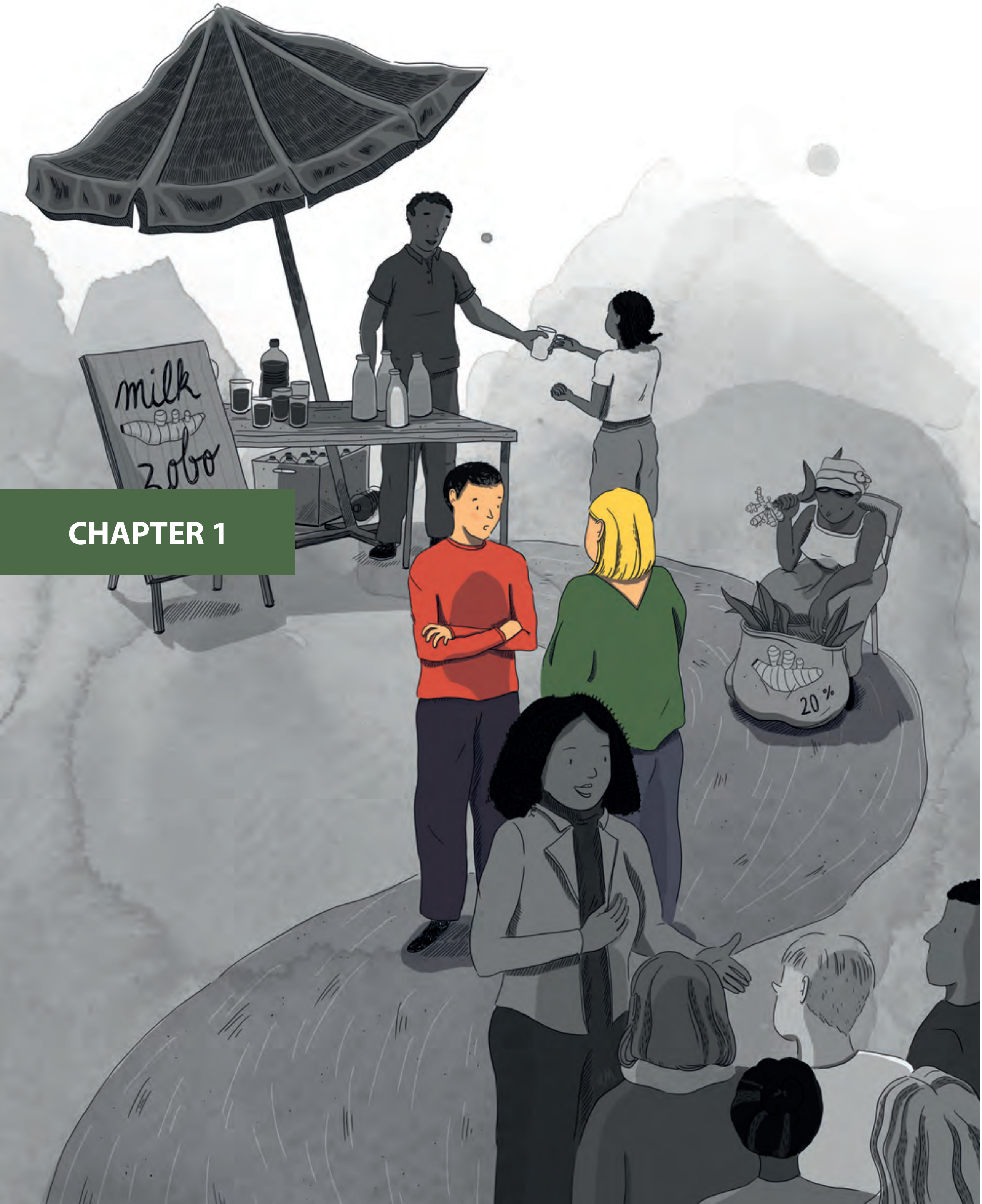
CHAPTER 1



General introduction and thesis outline

1.1 Background

At the end of the Millennium Development Goals (MDGs), member states of the United Nations agreed to an innovative set of changes, Sustainable Development Goals (SDGs), to be achieved by 2030. The 17 SDGs address issues such as poverty, hunger, inequality, education, wellbeing, ecological degradation, climate change, justice and peace, as well as their interactions.[1] However, SDG two has closely linked some sectoral problems like natural resources, education, gender equality, and employment to other SDGs.[2] Achieving the SDGs is a global challenge involving a wide range of actors, from government and policy leaders to individual consumers. However, the potential of the contribution of street-vended food to the SDGs has not been fully explored. Complete data on their contribution to the Sustainable Developmental Goals like poverty alleviation, food shortage eradication, food security, youth empowerment and employment benefit, malnutrition and mortality rate reduction in most countries are habitually nonexistent.

1.1.1 Street-vended foods processing, distribution, and consumption

Every day, an estimated 2.5 to 2.6 billion people globally consume street-vended foods (Fusté-Forné, 2021). The Food and Agriculture Organization (FAO) defined street-vended foods as ready-to-eat foods and beverages prepared and/or sold by vendors and hawkers, especially in streets and public places.[3] Similarly, the World Health Organization (WHO) characterized street-vended foods as meals or drinks sold on the streets and consumed without any further preparation.[4] Therefore, street-vended foods are similar to those offered at fast-food restaurants and other stores, with the exception that they are not sold in immobile locations. The street-vended foods have been reported to have significant economic, cultural, and social implications for the global food and nutrition system.[5-7] The street-vended food sector is also an established custom that may be found in various countries.

Figure 1.1 depicts street-vended food selling points in Nigeria. Street-vended food vendors commonly sell these foods in and near easily accessible locations, like the open markets (Fig. 1.1a and e), streets (Fig. 1.1b and d), parks, bus terminals, railway stations, hospitals, and schools (Fig. 1.1f), of developing countries. Food manufacturing companies and food cottages may process food to be sold on the street as in the case of the Miller sensation portrayed in figure 1.1c. Alternatively, street-vended foods may be processed by the vendors themselves, which is common in Africa, because the ingredients (Fig. 1.1a) used for production are sold in an open market where some of the street-vended food vendors also sell their products. Similarly, in developed nations, street-vended food vendors may be found at train stations, major shopping streets/city centres, and football stadiums. In the Netherlands, for instance, *oliebollen* (deep-fried dough/Dutch doughnuts), *patat* (French fries), *kroketten* (croquettes), *stroopwafels* (caramel-filled waffles), *kibbeling* (battered chunks of fried fish), *poffertjes* (small pancakes), *slagroom* (whipped cream) with hot chocolate and cake are available for purchase in these areas.[8]

Table 1.1 shows popular European street-vended foods and their African street-vended foods counterparts. As revealed in Table 1.1, the African street-vended foods and drinks are consumed globally, though the names given to these foods differ per continent or nation. However, in addition to the list in Table 1.1, the following foods are produced locally, sold on the street and consumed in Africa: *beske*, bread, beans, fried cocoyam, cake, egg rolls, chin-chin, buns, roasted plantain, *wara* (mozzarella, figure 1.1d) and maize (figure 1.1b), as well as fruits and vegetables, such as mango, pineapples, banana, oranges, watermelons, carrots and fluted pumpkins.

While street-vended food was initially primarily associated with developing countries' diets, its popularity in the developed world, particularly in North America and Eastern Europe, has grown significantly in recent years.[5, 9] Overall, the foremost street-vended foods of many nations are hotdogs, *tacos* and *burritos* (tortillas topped with a variety of fillings), hamburgers, finger foods, (America); popcorn, pastries, nuts, fruits, vegetables, ice cream, beverages (America, Africa, Asia and Europe); *bentos* (rice with beans and cooked vegetables served with meat and fish) for Brazil and Japan which is also consumed and known in Nigeria and Ghana as *iresi gateway* and *waakye*, respectively; *yakissoba* (noodles) for Brazil and China; *tempura* (battered shrimp in Asia); and pastries, churros, *acarajé* (a fritter made from out cowpeas) for Brazil and Caribbean which is also consumed and known in West Africa as *akara* and *kosai*.[10, 11]

In most developing countries, brewing and consumption of alcoholic beverages are also communal practices. In the region, alcoholic beverages are sold indiscriminately in the streets, motor parks, and open markets.[13]

a b c

d e f

Figure 1.1: A display of street-vended foods showing some of the ingredients and selling points in Nigeria. a= Kunnu (horchata) and masa (æbleskiver) ingredients, b= Maize and peanuts street-vended food vendors in Kano, c= Zobo (roselle) and Meat pie (burek) of Miller sensation (a cottage food business of a recent FUOYE-Food Science and Technology graduate), d= street-vended wara (mozzarella), f= Fura da nono (tzatziki) street-vended food vendors, g= Street-vended food vendor at primary school.

Ethnic alcoholic brewing is mostly a home-based enterprise in Asia and Africa, where rural women use their native skills of alcohol fermentation. Sorghum, millet, and maize are used to make these traditional brews. Malting, mashing, filtering, souring, boiling, and alcoholic fermentation are the basic unit processes involved in the manufacturing of African beers. Because they are not filtered, they are opaque and have a thick consistency, in contrast to European beers. Also, because they are allowed to undergo an acidification stage, these ethnic beers are sour. They are not bitter either because no hops are used in the manufacturing process. Furthermore, they tend to have an effervescent appearance because no attempt is taken to stop fermentation. African opaque beers are the common name for these ethnic beers. The common African opaque beers are, the Congolese *Gwalo*, Ethiopians *Bouza,* Ugandans and Kenyans *Busaa*, Sudanese *Merissa*, Tanzanians *Pombe* or *Bwalwa*, Setswanas *Bojalwa ja Setswana*, Basothos and South Africans *Yalwa*/*joule*, and *Utshwala*/*Tswhala*, Zimbabweans *Zezuru* and *Chibuki*, West Africans *Pito, Dolo, Tchapalo,* and *Burukutu*, and Banyarwandas *Ikigage*.[14-17]

1.1.2 Overview of intercontinental street-vended foods and drinks

Nigerians, like people in other developing nations, enjoy a variety of foods hawked on the street and in public places and even in traffic or expressways during congestion during rush hours. As a result of the latter scenario, these foods such as *masa*, yam, and rice and stew serve as breakfast, lunch and dinner for people in the cities.[18] Additionally, there are street-vended drinks to complement these foods sold on the street. The complementary street-vended drinks widely consumed include *zobo* made from dried hibiscus (*Hibiscus sabdariffa*) calyces; soya milk; and *kunnu* made from cereals like sorghum (*Sorghum bicolor*), millet (*Pennisetum glaucum*), maize (*Zea mays*), rice (*Oryza sativa*), and '*acha'* fonio (*Digitaria exilis*). The production, distribution, and consumption of these locally made beverages are high in Nigeria due to the tremendous cost of industrially made and imported drinks.

Table 1.1: Popular European street-vended foods* and their African counterparts

Country	Street-vended foods' distinctive/national name	Similar African street-vended foods
Austria	*Kaiserschmarnn, Käsekrainer, Bratwurst, Frankfurter, Currywurst*	
Balkan	*Burek*	Meat pie (Nigeria, Ghana, South Africa, Zimbabwe)
Belarus	*Nalistniki*	
Belgium	*Frieten met Mayonnaise*	*Dundun, odunkun* (South-West Nigeria) *Yamarita* (Northern Nigeria) *batata* (East and West Africa)
Denmark	*Æbleskiver*	*Masa* (West Africa)
	Pork loin sandwich with sweet and sour red cabbage, Pork loin with crisp crackling	
France	*Crêpes*, Traditional hot wine with Alsace	
Germany	*Crêpes, Buletten or Frikadellen*	
Greece	*Souvlaki,*	*Suya, tsire* (Nigeria), *Agashe* (Sudan), *chinchinga, sitsinga* (Ghana)
	Koulouri (Greek sesame ring bread),	
	Tzatziki	*Fura da nono* (West Africa)
The Netherlands	*Oliebollen*	*Puff-puff* (Nigeria and Sierra Leon), *bofrot* (Ghana), *beignets* (Cameroon), *amagwinya, vetkoets* (South Africa), *gbofloto* (Ivory Coast), *maglia* (Eritrea), *gateaux, farine* (Gabon), *kala* (Liberia), *magwinya* (Botswana), *mandasi* (Malawi), fat cooks/cakes (Zimbabwe)
	Fried fish and Kibbeling	*Eja dindin* (South-West Nigeria), *kifi* (Northern Nigeria), *kyenam* (Ghana)
Norway	*Fiskekaker, Lomper*	
Poland	*Kremówka Papiesk, Zapiekanka*	
Romania	*Mititei/Mici*	*Kilishi* (Nigeria), *biltong* (Botswana, South Africa, and Zimbabwe)
Russian Federation	*Pirozhki*	Meat pie (Nigeria, Ghana, South Africa, Zimbabwe)
	Shashlik	*Suya, tsire* (Nigeria) *Agashe* (Sudan), *chinchinga, sitsinga* (Ghana)
Turkey	*Izgara* *Kimyonlu Köfte*	
	Nohutlu Pila	*Iresi atewa* (South-West Nigeria) *Shinkafa da wake* (Northern Nigeria), *Waakye* (Ghana)

*Adapted from Barone and Pellerito[12]

Masa: *Masa*, also known as *waina*, is a fermented cereal (commonly rice, millet, maize, or sorghum) puff batter fried in a pan with individual cup-like depressions, Figure 1.2. *Masa* is consumed in a variety of ways by people of all ages as food or with local soup in Nigeria and other West African countries.[18] It is comparable to Danish *æbleskiver*, Dutch *poffertjes*, and Indian *idli*. *Masa* has also been referred to as a staple food product within the Hispanic community in the United States.[19] Apart from its short shelf-life, *masa* has a poor protein level, and inconsistency in the use of different cereals and spices has also resulted in product quality variance.[20, 21]

Kunnu: *Kunnu*, Figure 1.3 is a cheap, non-alcoholic locally manufactured beverage that is commonly drunk by a wide range of people, from the young to the old, in West Africa as a weaning food, refreshing drink, food supplement, and thirst quencher. It is also served as an appetizer and is frequently used in social gatherings. *Kunnu* is a pleasant drink similar to Americans and Spanish *smile de jicaro* and *horchata*.

Figure 1.2: *Masa* production and sales in Kano and Ilorin, Nigeria

As the Spanish *horchata* made from tiger nuts, rice, sesame, and melon are named *horchata de chufa*, *horchata de arroz*, *horchata de ajonjoli*, and *horchata de melon* respectively, also in Nigeria, the types of cereal and nut used to make *kunnu* defines its variety. For instance, *kunnu aya* comprises tiger nuts, millet, sorghum or maize; *kunnu gyada* is made up of rice, peanut, sorghum or millet; *kunnu tsamiya* is composed of millet, sorghum, or rice; *kunnu zaki* is composed of millet, sorghum, or maize; and *kunnu gayamba* is made up entirely of millet.[22] Spices and herbs such as ginger (*Zingiber officinalis*), alligator pepper (*Aframomum melegueta*), red pepper (*Capsicum* sp.), and black pepper (*Piper nigrum*) are frequently added to the main ingredient.[23-25] Though the cereal grains (Fig. 1.1) can be used individually or collectively, all the spices are mixed and the quantity varies among the street-vended food vendors. The traditional method for making *kunnu* includes steeping grains for 8–72 h, wet grinding with spices, sieving, and partial gelatinization of the slurry, then adding sugar and bottling (Fig. 1.3). Lactic acid bacteria and yeast are primarily involved in the short fermentation that happens during grain steeping.

Figure 1.3: Street-vended *kunnu* at Ibadan, Nigeria

The product has a shelf life of around 24 h at room temperature, which can be prolonged to 8 days by pasteurization at 60°C for 1 h and storage in unrefrigerated circumstances.[13, 20]

<u>*Burukutu* and *Pito*</u>: Cereal-based drinks are viewed as food in Africa by consumers since they fulfil hunger and have a good taste.[26] *Burukutu* and *pito*, are thus popular in West African countries due to their characteristic filling, refreshing, and low cost. *Burukutu* and *pito* are alcoholic beers made from millet, sorghum, or maize. As street-vended drinks (Fig. 1.4), both *burukutu* and *pito* are made and sold by local women to support their families. The methods of making these alcoholic beverages are similar, with the exception that in the production of *burukutu*, certain additives such as *garri* (cassava granules), ground malt, and water in a ratio of 1:2:6, *garri*: malt: water, are introduced during the mashing process, whereas in the production of *pito*, such additions are not used. Traditional *burukutu* and *pito* preparation is a batch process done twice or three times a week on a small scale. Boiling before maturation removes lactic acids and other yeast in *burukutu*. The acetic acid percentage of fully matured *burukutu* beer ranges between 0.4 and 0.6%.[20] *Pito* drink, Figure 1.4 is a dark brown liquid with a taste that ranges from sickly-sweet to sour and contains lactic acid, carbohydrates, and amino acids, as well as a 3% alcohol content.[20]

<u>Soya milk</u>: Soya beans and their products, such as *beske*, *tempeh*, and soya milk have become more popular in Africa during the last two decades due to their high protein content (39%) and low cost compared to animal protein.[23, 27] *Beske* is a soya bean-based deep-fried snack in Nigeria produced by coagulating soya milk which is known as *tofu* in Asia countries.[28] *Tempeh* is a fermented soya bean food that has been consumed for centuries in Indonesia and is also recognized around the world. Amin and Kusnadi[29] identified the Americas, Africa, Australia, Europe and Asian countries specifically China, Japan, and Taiwan, as high *tempeh* consumers. Soya milk has also been a traditional beverage in Asia for centuries.[30]

Figure 1.4: *Pito* vended at ever-busy Agodi-gate moto park, Ibadan, Nigeria

Developing countries' diets lack animal sources of protein, such as milk, which are costly and out of reach for low-income households. As a result, soya milk (a cheap source of protein) is used to supplement such diets and became popular in developing countries. In the Western world, health-conscious people consume more soya-based products than ever before because of their health benefits.[31] Besides, one of the key reasons contributing to the harmful impact of the modern diet on climate and individual health is the consumption of high quantities of animal-based products, particularly those obtained from cows, such as milk. Consequently, there is a lot of interest in changing to a more plant-based diet to improve human health, boost food sustainability, and reduce pollution, land use, and water use. This change has currently led to a variety of rice, almond, tiger nut, oat, cashew nut, coconut, and soya-based milk analogues in the market.[27, 31, 32]

Plant-based milk analogues are drinks made from the size reduction of plant material (cereals, legumes, oilseeds, nuts) extracted in water, followed by homogenization, resulting in a particle size distribution in the 5–20 μm range, which looks like cow's milk in appearance and consistency.[30] Although the nutritional values of these milk analogues are comparable to those of cow milk, many consumers are hesitant to switch to plant-based kinds of milk because they dislike the flavour.[31, 33] Soya beans are therefore been processed into soya milk by milling, sifting, boiling, cooling, and adding flavouring and sweeteners. Soya milk has also been fortified with other plants like banana, carrot, coffee, orange, pineapple, cocoa, and ginger to mask the beany flavour and to encourage more soya milk consumption for improved nutrition.[33, 34]

Zobo: *H. sabdariffa*, a member of the Malvaceae family, is an annual herb that grows in tropical and semi-tropical climates. Table 1.2 presented the nutritional composition of *H. sabdariffa* calyces. In several countries across the world, *H. sabdariffa* is used to make a variety of food and beverage products. The fleshy red calyxes are often utilised in the manufacturing of soft beverages, juice, jam, jelly, and syrup, as well as being dried and brewed into tea and drinks.[35, 36] For *H. sabdariffa* drink production the hibiscus calyces are boiled or soaked in water to make the drink.[36-38]

A drink from *H. sabdariffa*, known as *zobo* (Fig. 1.5) in Nigeria is consumed by individuals from all socioeconomic groups.[39] Sales of *zobo* assists as a source of income for several families because of the ease of production and availability of raw materials, particularly *H. sabdariffa*.[40] *Zobo* is filled into plastic bottles for sale on the street and served during marriages, birthdays, and naming ceremonies, as shown in Figures 1.1 and 1.5. Currently, *zobo* consumption is not limited to West African countries, particularly among the youth, who see *zobo* as a reasonably inexpensive and soothing non-alcoholic drink in social gatherings. In Asia, Australia, Central America, Europe, and the rest of Africa, *zobo* is been consumed but known as roselle and has a variety of regional names like cranberry, *kumbang, karkade, karkanji, bissap*, *asam beland*a, *Indian sorrel, ribena, flor de Jamaica* and *Congo*.[36, 41]

Zobo can be produced in diverse ways with dried calyces and a variety of ingredients. The dried calyces: water ratio of street-vended *zobo* have been reported to be in the range of 1:57 to 1:71 (w/v), while the extraction period varies from 30 min to 12 h (overnight), with the extraction temperature remaining constant at 100°C ± 2.[36, 42] Individual processors choose their own preservatives and flavours for their drinks.

All the methods produce the same drink, but with slightly varied flavours because of the sweeteners (sugar, honey, pineapple juice, sugar cane, and maple syrup) and aromas from the spices and natural preservatives used. Garlic and ginger, lemon, clove, cinnamon, and nutmeg, are commonly used.[24, 43-45] Other plant crops such as candy leaf (*Stevia rebaudiana*) and pepper fruit (*Dennettia tripetala*) have been used as a substitute for sweeteners and spice (specifically ginger), respectively in the preparation of fortified *zobo*.[38, 46]

Overall, water is the most prevalent ingredient in street-vended drinks. Water serves as the medium in which all other constituents are dissolved, as well as lowering the cost of production.

Table 1.2: Nutritional composition* of *H. sabdariffa* calyces

Parameter	Content/100 g fresh calyces
Fats (g)	2.6
fibre (g)	12.0
ash (g)	6.9
calcium (mg)	12.6
protein (g)	1.2
phosphorus (mg)	2732
iron (mg)	8.98
carotene (mg)	0.03
niacin (mg)	3.77
thiamine (mg)	0.12
ascorbic acid (mg)	1.70
riboflavin (mg)	0.28

*Source: Sulieman[40]

Figure 1.5: *Zobo* street vendors with turmeric and lemon for sale at Ikole-Ekiti open market

Given the expanding popularity and socio-economic abilities, it has been reported that if well processed, packaged, and fortified, these street-vended drinks will compete favourably with most imported drinks available in Nigeria.[47]

1.2 The contribution of street-vended foods to human diets

Steyn and Mchiza[48] reviewed the importance of street-vended food vendors in delivering safe and healthy foods to consumers. In developing nations specifically, lower-income individuals spend 50–70% of their household incomes on street-vended food including giving money to schoolchildren to buy food and drinks during lunch instead of cooked food, prepared snacks, and beverages by parents. Likewise, street-vended foods also serve as the primary food source for many adults in the developed nation.[12] Thus the street-vended food vendors and the contribution of street-vended foods to diets are discussed briefly in this section.

Street-vended food vendors: The street-vended food vendors are a growing segment of the informal sector.[49] In developing countries, the underprivileged are primarily involved in this sector, which has been interpreted as a lack of regular work. Because most of the fast-growing urban population in the developing nations has not been absorbed into the formal labour force, many have turned to a variety of self-employed, money-generating activities, such as street-vended food selling, to supplement their income. Many street-vended food vendors especially women and youth in these nations and their families also rely on the food sold as their principal food source.[50]

Cost: When compared to other food options, street-vended food is reasonably priced. Because many people work long hours, eating street-vended food saves time in the kitchen as street-vended foods are frequently available in modest quantities. In developed countries, fuel costs are rising rapidly, and purchasing street-vended foods saves not just on labour time but also energy expenditures. Furthermore, because many poor individuals lack proper cooking equipment and space, buying street-vended foods is beneficial in developing countries. Overall, the low cost of street-vended foods could be the most crucial factor in its remarkable success.

Nutrition: Street-vended foods provide a substantial nutritional benefit to people because of the significant amount of bioavailable proteins and energy intake. According to the literature, the nutrient contributions from street-vended foods to daily energy intake (EI) in adults were reported as: Abeokuta in Nigeria (50.3% EI in males; 48.3% EI in females), Ouagadougou in Burkina Faso (46% EI), Nairobi in Kenya (27–36% EI in males; 13–22% EI in females), Uganda (22.4–25.6% EI) and Bamako in Mali (18.3% EI). In children, studies have demonstrated the contribution of street-vended foods to daily energy intake. These include Cotonou in Benin (40% EI), Nairobi in Kenya (13.4–22.4% EI), Port-au-Prince in Haiti (25% EI), Bamako in Mali (18.3% EI), and 19% EI in Hyderabad, India.

Among Haiti, street-vended meals provided 16% of the RDA for protein in high school students.

The average daily protein consumption (62 g) from street-vended foods provided more than half of the RDA in Nigerian teenagers. Street-vended foods provided 53.2% of men's and 50.7% of females' total daily protein intake among Nigerian adults. Similarly, lunches sold to workers in Nairobi provided more than half of the RDA for protein. Street-vended foods provided 41%, 19%, and 9% of daily protein intake in people of high, middle, and low socioeconomic level (SES), respectively, in Mali, and 38.6–44.9% of daily total protein intake in Uganda. A typical street supper in Calcutta in India had 20–30 g of protein.[48]

More than 40% of fat and carbohydrates in Benin come from street cuisine. The rich group consumed 20–30% of their daily fat consumption from street meals, compared to 15% in the low-SES group. Adults in Nigeria consumed 38% of their total daily fat intake and 54% of their total daily carbohydrate intake from street-vended foods. Street-vended foods contributed 52% of daily fat intake and 72% of daily sugar intake for women in Burkina Faso. In Calcutta, a 500 g street-vended food dinner had 12–15 g of fat.[48]

Information on the micronutrient content of street-vended foods is scarce. Similarly, there is limited data on the contribution of street-vended foods to the intake of micronutrients. Overall, because of the popularity of street-vended foods, any nutritional enhancements to these foods and drinks are likely to benefit a significant number of people globally. Food-to-food fortification is one method of supplementing street-vended foods and beverages, and it would provide a solution for the people without extensively altering food consumption patterns.

1.3 Turmeric (*Curcuma longa* L.) as a food-to-food fortification approach to improving the quality of street-vended foods

Consumers in developing nations are becoming more aware of the strong link between food and health, therefore functional foods would appeal to them.[51] However, due to a lack of access to these types of foods and higher costs, they have been forced to turn to more readily available and cheap foods with a lower nutritional value, which are sold on the street and easily accessible. Some of these foods are high in calories and contribute to the burden of malnutrition in the region. On the other hand, in the developed nations, growing concern about the negative health effects of modern diets high in refined sugar and fat which are known to be the main causes of obesity, diabetes, cardiovascular disorders, and degenerative diseases like cancer, has sparked renewed research interest in underutilised minor crops rich in health-promoting bioactive compounds.[52]

Turmeric (*Curcuma longa* L.), like ginger, is a subterranean rhizome that belongs to the Zingiberaceae family and is one of the minor crops that is gaining popularity in people's diets globally. In India, turmeric is known as *Haldi* and *Manjal*, with various local names depending on the region. Same in Nigeria, turmeric is known by a variety of regional names, including *Atale pupa*, *Gangamau*, and *Onjonigho*. It is called *Geelwortel* in Dutch, Curcuma in French, German, Italian, Romanian, and Spanish. It is also known as *Kurkuma* in Bulgarian, Danish, Hungarian, Lithuanian, Norwegian, Polish, and Ukrainian. It is known as *Kurkum* in Arabic, *Yu Chiu* in Chinese, *Kitrinoriza* in Greek, *Kunir* in Indonesia, *Ukon* in Japanese, *Kang-hwang* in Korean, *Gurkemeja* in Swedish, *Acafrao* in Portuguese, *Imbir Zhyoltyj* in Russian, and *Nghe* in Vietnamese.[53]

Turmeric is sold in two forms: fresh (roots) and dry (powder). Turmeric is mostly made up of 60% turmerone, 25% zingiberene, and 1.5–5% volatile oils. Turmeric, which is commonly used as a colourant, can also be used as a flavouring component in food. It contains three curcuminoids that give turmeric its yellowish tinge. These curcuminoids are diferuloylmethane commonly known as curcumin (71.5–94%), demethoxy-curcumin (6–19.4%), and bisdemethoxycurcumin (0.3–9.1%).[54] India is the world's largest producer and user of turmeric, as well as the leading exporter. India dominates the global production sector with 78%, followed by China (eight percent), Myanmar (four percent), Nigeria, and Bangladesh, both of which account for six percent of world production.[55]

Turmeric has been conventionally used for centuries as a medicinal herb in Asiatic for its antioxidant, antibacterial, antimigraine, anti-inflammatory, and anticancer characteristics, but it is now becoming popular and used in a variety of ways across the globe due to its numerous potentialities. Turmeric is used in curry in India, tea in Japan, cosmetics in Thailand, dye in China, antiseptic in Malaysia, anti-inflammatory agent in Pakistan, and preservative and colourant in mustard sauce, fries, butter, and cheese, in the United States.[56] Turmeric has also been used as a food preservative as well as for non-food applications such as medical (including malaria, stomach aches, typhoid fever, cough, and skin disorders), cosmetics and dye in Nigeria and other parts of Africa.[57-61] To use turmeric in food-to-food fortification, the production, processing, consumption, and utilisation of the spice should all be encouraged, beginning with the growing areas.

1.3.1 Turmeric production and processing in Nigeria

Turmeric thrives in clay loam or well-drained sandy soil with temperatures ranging from 20 to 30°C and an annual rainfall of 1500 mm or higher.[62] Turmeric has been reported to grow at a low altitude of five meters above sea level in the rainforest's southern seaside plains and at a mid-altitude of 823 m above sea level in Nigeria's derived savanna (longitude 3°02′E–09°30′E and latitude 4°37′N–10°04′N).[63] Nigeria contributes about three percent of the world's turmeric production because of its favourable soil and weather conditions. Depending on the time of seeding, the crops are available for harvest in seven to nine months. The harvest takes place from January to March. It takes roughly 9 months to reach full maturity. From February until May, the marketing season is in full swing.[64] At maturity, the crop's leaves get dry and are light brown and yellowish in colour as shown in Figure 1.6. The crop's height is roughly 1.5 feet after complete growth, with a maximum of 8-10 branches and cracks developing on the soil, indicating good yields of turmeric. Typically, the area is ploughed, and the rhizomes are collected by hand plucking (Fig. 1.6) or carefully lifting the clumps with a spade. Harvested turmeric is stored after it has been cleaned of mud and other foreign matters that have adhered to rhizomes. Turmeric yield per unit area is quite low due to farmers' lack of understanding of the correct growing technology in Nigeria.[62] Furthermore, the processing of turmeric is impeded by a lack of machines and equipment to perform various operations.[64] Weeds can reduce crop productivity and increase total labour costs.

Turmeric production also necessitates a lot of bed mulching. For maximum production, mulching helps to conserve moisture, promote germination, reduce weeds, regulate soil temperature, give nutrients to the soil, and improve soil physical fertility. Elephant grass is used to mulch at a rate of 12 t/ha in Nigeria.[64] The first mulching is usually done just after planting, and the second mulching is eight weeks later. To increase job opportunities, boost farmer income, and benefit the country, the "Turmeric Promotion and Awareness Program" by the National Root Crops Research Institute (NRCRI), located in Umudike, has identified several research interventions focused on upgrading turmeric production and processing in Nigeria.

1.3.2 Emphasis on the significant accomplishments of about two decades of turmeric research in Nigeria

National Root Crops Research Institute, Umudike was the foremost to gather turmeric germplasm and indigenous knowledge about its cultivation and utilisation in Nigeria.[65] The institute obtained a total of 76 turmeric accessions during several missions across Nigeria (from 2004 to 2006) and conducted multi-locational testing in Jos, Otobi, Umudike, and Igbariam. Ten genotypes, accessions 6, 14, 35, 38, 39, 41, 44, 46, 50 and 58, were found to be promising and are receiving more investigation before being officially registered and released to farmers.[65]

Chinedum, Kate[66] investigated the antioxidant activities and polyphenol composition of accessions 35, 39, 41 and 50. The curcumin, antioxidants, alkaloids, flavonoids, anthocyanins, and phenolics contents of these turmeric accessions were comparable to literature reports for turmeric grown in other nations. In that same 2015, accession 14 was examined for a "possible short term storage effect on some chemical properties".[67] Because the ten promising accessions will ultimately be released to Nigerian farmers to boost turmeric cultivation in Nigeria, we wrote to the institute in 2017 to know if there is a reason(s) why these five (14, 35, 39, 41 and 50) accessions were used in the research by Chinedum, Kate[66] and Etudaiye, Ukpabi.[67]

Figure 1.6: Turmeric farm visited during 2016 harvest season in Ekiti state Nigeria

Also, to know if the ten selected genotypes have been officially registered and already available for farmers and consumers, but we got no response. Eventually, the turmeric used in this study was sourced from Ekiti since NRCRI got the highest number (12) of turmeric accession collections in the state and the state has also been reported as the highest producer of turmeric in Nigeria.[57, 65]

Furthermore, the Amadi, Olojede[65] report highlighting the substantial attainments from almost twenty years of turmeric research at NRCRI Umudike, Nigeria, showed that:

- Agronomic management for maximising turmeric yield in Nigeria has been developed.
- Turmeric production is highly profitable regarding returns per naira (R/N) and benefit-cost ratio in the economic studies investigation.
- Turmeric powder, for example, has been developed as a value-added product.
- Turmeric production and value-added products skills extended to farmers and other end users.

- Turmeric's chemical composition and prospective usage as a food colourant have been determined.

1.4 Objectives and research questions

In food-to-food fortification, it is important to have access to and employ fortificants that are well absorbed while not affecting food's sensory characteristics. These could have been part of the reasons why turmeric as a fortificant is becoming increasingly popular globally. Furthermore, many people believe that turmeric-fortified foods are nutritionally beneficial. All these claims must be scientifically validated. Thus, the general objective of this thesis was to support the use of turmeric in traditional foods to advance the livelihoods of the local population through better nutrition and increase trade opportunities in its production areas. This thesis specifically targeted Nigeria where the government is currently promoting the cultivation of turmeric to improve rural livelihoods.

To attain the general objective, the thesis addressed the effect of processing and food matrix on the antioxidant and nutritional quality of turmeric-fortified street-vended *zobo* drink and soya milk.

Overall, the specific objectives of the thesis were to:

- Collect information about traditional methods of processing and utilisation of turmeric;
- Critically review studies on how consumers appreciate the use of turmeric in traditional and ethnic foods;
- Examine the consumer acceptability and attitudes of Nigerians to novel turmeric-fortified drinks;
- Investigate if adding turmeric will improve the nutritional and antioxidant qualities of the developed turmeric-fortified street-vended drinks; and

- Assess bioaccessibility of curcumin in turmeric-fortified street-vended drinks.

In Figure 1.7, the research questions that were designed to address these goals are depicted schematically.

1.4.1 Thesis outline

This general introduction provides information on Nigerian street-vended foods, their processing, consumption, global equivalents, and contributions to human diets/SDGs. Turmeric production in Nigeria and turmeric as a food-to-food fortification approach to improve the antioxidant and nutritional qualities of the street-vended foods are described in this section. The chapter also describes the research problems that this thesis addresses. **Chapter 2** appraised consumers' perception of introducing a new ingredient in food – the case of turmeric. In **chapter 3**, findings on attitudes towards novel turmeric-fortified drinks are described based on food neophobia studies among Nigerian consumers. **Chapters 2 and 3** recognized areas of impending research, which served as a basis for **chapters 4 and 5**.

Chapter 4 gives an overview of enriching street-vended *zobo* drink with turmeric to increase its health-supporting properties. The effect of concentration and processing (boiled turmeric root and turmeric paste added to *zobo* in varying quantities) on the antioxidant and nutritional qualities of *zobo* drink were determined. Subsequently, **chapter 5** studies the effect of changing matrix milk-based (cow milk vs soya) and water-based (*zobo*), the amount of turmeric paste (0%, 2% and 6%), and the impact of heating (with and without) on antioxidant and nutritional properties of the golden milk. Finally, **chapter 6** presents the general discussion of the main findings using the food and nutrition system approach. **Chapter 6** also includes limitations of this study, concluding remarks and recommendations for future research.

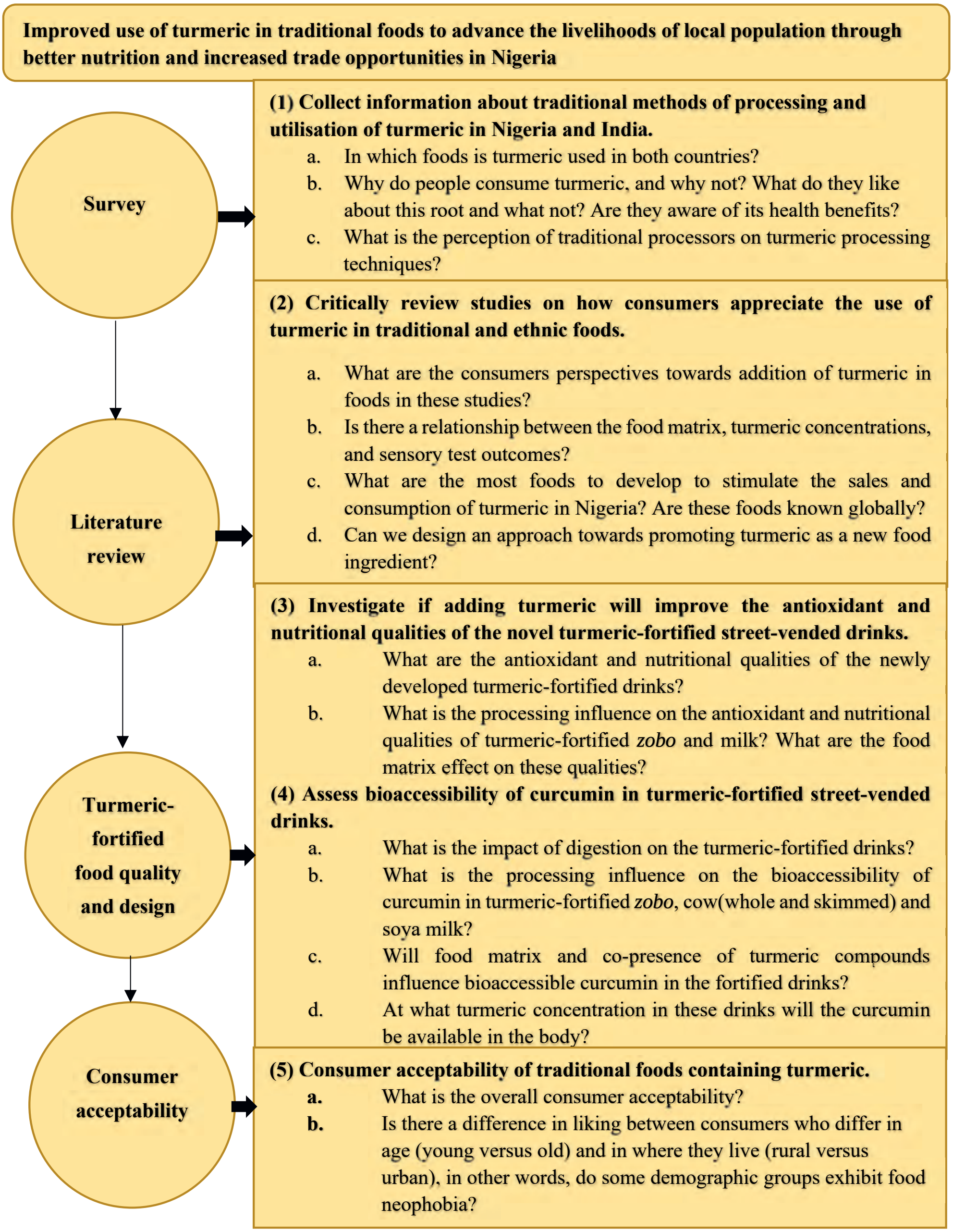


Figure 1.7: Flow chart of the chronological activities included in the PhD research project

References

1. Assembly U. Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. United Nations Statistics Division: New York, USA. 2017.

2. Poole N, Bentley A, Donovan J, Erenstein O, Ibba M, Palacios-Rojas N. Food security, nutrition and health: implications for maize and wheat research and development. 2021.

3. FAO. Street Foods-Report of an FAO Expert Consultation Yogyakarta, Indonesia, 5-9 December 1988: Food Agriculture Organization of the United Nations; 1990.

4. WHO. Essential safety requirements for street-vended foods. World Health Organization; 1996.

5. Fusté-Forné F. Street food in New York City: Perspectives from a holiday market. International Journal of Gastronomy and Food Science. 2021;24:100319.

6. Kraig B, Sen CT. Street food around the world: an encyclopedia of food and culture: An Encyclopedia of Food and Culture: Abc-clio; 2013.

7. Abrahale K, Sousa S, Albuquerque G, Padrão P, Lunet N. Street food research worldwide: a scoping review. Journal of Human Nutrition and Dietetics. 2019;32(2):152-74.

8. Cade D, Curran K, Fuller A, Hacker J, Knight C, Lansley S, et al. Perspectives from those involved in healthy stadia. Sport in Society. 2017;20(2):187-201.

9. Albuquerque G, Gelormini M, de Morais IL, Sousa S, Casal S, Pinho O, et al. Street food in Eastern Europe: a perspective from an urban environment in Moldova. British Journal of Nutrition. 2020;124(10):1093-101.

10. Nonato I, Minussi LDA, Pascoal G, De-Souza D. Nutritional issues concerning street foods. Journal of Clinical Nutrition & Dietetics. 2016;2(1):1-7.

11. Cohen E, Avieli N. Food in tourism: Attraction and impediment. Annals of Tourism Research. 2004;31(4):755-78.

12. Barone M, Pellerito A. The Street Food Culture in Europe. Sicilian Street Foods and Chemistry: Springer; 2020. p. 1-19.

13. Nwaiwu O, Aduba CC, Igbokwe VC, Sam CE, Ukwuru MU. Traditional and Artisanal Beverages in Nigeria: Microbial Diversity and Safety Issues. Beverages. 2020;6(3):1-22.

14. Atter A, Obiri-Danso K, Amoa-Awua W. Microbiological and chemical processes associated with the production of *burukutu* a traditional beer in Ghana. International Food Research Journal. 2014;21(5):1769-76.

15. Tamang JP. Diversity of fermented beverages and alcoholic drinks. Fermented Foods and Beverages of the World: CRC Press; 2010. p. 97-138.

16. Lyumugabe F, Uyisenga JP, Songa EB, Thonart P. Production of traditional sorghum beer "*Ikigage*" using *Saccharomyces cerevisae*, *Lactobacillus fermentum* and *Issatckenkia orientalis* as starter cultures. Food and Nutrition Sciences. 2014;5:507-15.

17. Akinyoade A, Ekumankama O, Uche C. The use of local raw materials in beer brewing: Heineken in Nigeria. Journal of the Institute of Brewing. 2016;122(4):682-92.

18. Ene-Obong HN, Sanusi RA, Udenta EA, Williams IO, Anigo KM, Chibuzo EC, et al. Data collection and assessment of commonly consumed foods and recipes in six geo-political zones in Nigeria: Important for the development of a National Food Composition Database and Dietary Assessment. Food Chemistry. 2013;140(3):539-46.

19. Hamner HC, Tinker SC. Fortification of corn *masa* flour with folic acid in the United States: an overview of the evidence. Annals of the New York Academy of Sciences. 2014;1312:8-14.

20. Adeyeye SAO. Safety issues in traditional West African foods: a critical review. Journal of Culinary Science & Technology. 2017;15(2):101-25.

21. Samuel FO, Ishola OR, Otegbayo BO. Nutritional and sensory evaluation of rice-based *Masa* Enriched with Soybean and Crayfish. Food and Nutrition Sciences. 2015;6(02):234.

22. Ezekiel CN, Ayeni KI, Ezeokoli OT, Sulyok M, Van Wyk DA, Oyedele OA, et al. High-throughput sequence analyses of bacterial communities and multi-mycotoxin profiling during processing of different formulations of *Kunnu*, a traditional fermented beverage. Frontiers in Microbiology. 2019;9:3282.

23. Fasoyiro S. Locally processed street-vended foods in Nigeria: how safe? International Journal of Safety and Security Engineering. 2012;2(4):381-91.

24. Umaru GA, Tukur IS, Akensire UA, Adamu Z, Bello OA, Shawulu AH, et al. Microflora of *Kunun-Zaki* and *Sobo* drinks in relation to public health in Jalingo Metropolis, North-Eastern Nigeria. International Journal of Food Research. 2014;1:16-21.

25. Olosunde O, Abiodun O, Amanyunose A, Adepeju A. Sensory and nutritional characteristics of *kununzaki* enriched with moringa (*Moringa oleifera*) seed flour. Journal of Experimental Agriculture International. 2014:1027-35.

26. Fadahunsi I, Ogunbanwo S, Fawole A. Microbiological and nutritional assessment of *burukutu* and *pito* (indigenously fermented alcoholic beverages in West Africa) during storage. Nature and Science. 2013;11(4):98-103.

27. Oyeyinka AT, Odukoya JO, Adebayo YS. Nutritional composition and consumer acceptability of cheese analogue from soy and cashew nut milk. Journal of Food Processing and Preservation. 2019;43(12):e14285.

28. Bagirei S, Mohammad Y, Maude M, Abdulkadir F, Umar S. Evaluation of Sensory Qualities of *Awara* and Performance on Yield and Functional Properties of Fresh and Dried Soy-curds. International Journal Of Science for Global Sustainability. 2021;7(2).

29.Amin MNG, Kusnadi J, Hsu J-L, Doerksen RJ, Huang T-C. Identification of a novel umami peptide in *tempeh* (Indonesian fermented soybean) and its binding mechanism to the umami receptor T1R. Food Chemistry. 2020;333:127411.

30. Sethi S, Tyagi SK, Anurag RK. Plant-based milk alternatives an emerging segment of functional beverages: a review. Journal of Food Science and Technology. 2016;53(9):3408-23.

31. McClements DJ, Newman E, McClements IF. Plant-based milks: A review of the science underpinning their design, fabrication, and performance. Comprehensive Reviews in Food Science and Food Safety. 2019;18(6):2047-67.

32. Clemente-Villalba J, Cano-Lamadrid M, Issa-Issa H, Hurtado P, Hernández F, Carbonell-Barrachina ÁA, et al. Comparison on sensory profile, volatile composition and consumer's acceptance for PDO or non-PDO tigernut (*Cyperus esculentus* L.) milk. LWT. 2021;140:110606.

33. Sęczyk Ł, Świeca M, Gawlik-Dziki U. Soymilk enriched with green coffee phenolics–Antioxidant and nutritional properties in the light of phenolics-food matrix interactions. Food Chemistry. 2017;223:1-7.

34. Oladele Dauda A, Adunni Abiodun O. Comparative study of the effect of dry and wet ginger (*Zingiber officinale*) spice on the proximate and microbial safety of soybean beverage. Croatian Journal of Food Science and Technology. 2017;9(2):130-5.

35. Singh P, Khan M, Hailemariam H. Nutritional and health importance of *Hibiscus sabdariffa*: a review and indication for research needs. Journal of Nutritional Health Food Engineering. 2017;6(5):00212.

36. Salami SO, Afolayan AJ. Suitability of Roselle-*Hibiscus sabdariffa* L. as raw material for soft drink production. Journal of Food Quality. 2020;2020.

37. International Organization for Standardization. Tea-preparation of liquor for use in sensory tests. International Organization for Standardization ISO 3103, 2019, Geneva, Switzerland. 2019.

38. Saraswati A, Taniwiryono D. Formulation of ready to drink (rtd) made from roselle (*Hibiscus sabdariffa.* L) tea and stevia (*Stevia rebaudiana*) leaf safe for diabetics. Indonesian Journal of Applied Research (IJAR). 2020;1(1):1-9.

39. Izah SC, Orutugu LA, Kigigha LT. A review of the quality assessment of *zobo* drink consumed in Nigeria. ASIO Journal of Microbiology, Food Science and Biotechnology Innovations. 2015;1(1):34-44.

40. Sulieman AME. Antimicrobial activity of Roselle (*Hibiscus sabdariffa* L.) seed oil. In: Mariod AA, editor. Multiple Biological Activities of Unconventional Seed Oils: Elsevier Academic Press; 2022. p. 91-100.

41. Idowu-Adebayo F, Fogliano V, Oluwamukomi MO, Oladimeji S, Linnemann AR. Food neophobia among Nigerian consumers: a study on attitudes towards novel turmeric-fortified drinks. Journal of the Science of Food and Agriculture. 2021;101:3246-56.

42. Bolade M, Oluwalana I, Ojo O. Commercial practice of roselle (*Hibiscus sabdariffa* L.) beverage production: Optimization of hot water extraction and sweetness level. World Journal of Agricultural Sciences. 2009;5(1):126-31.

43. Ezeigbo O, Ekaiko M, Agomo N, Ojukwu K, Nnadozie A. Antimicrobial effect of lime juice treatment on the shelf-life of *zobo* drink. British Microbiology Research Journal. 2015;6(3):147.

44. Egbere O, Anuonye J, Chollom P, Okpara P. Effects of some preservation techniques on the quality and storage stability of *zobo* drink (A Nigerian, non-alcoholic beverage from *Hibiscus sabdariffa*). Journal of Food Technology. 2007;5(3):225-8.

45. Nwachukwu E, Onovo O, Ezeama C. Effect of lime juice on the bacterial quality of *zobo* drinks locally produced in Nigeria. Research Journal of Microbiology. 2007;2(10):787-90.

46. Ihemeje A, Ojinnaka M, Obi K, Ekwe C. Biochemical evaluation of pepper fruit (*Dennettia tripetala*) and its use as substitute for ginger in *zobo* drink production. Academic research international. 2013;4(6):513.

47. Adelekan A, Arisa N, Alamu A, Adebayo Y, Popoola G. Production and acceptability of fruits enhanced *zobo* drink. Food Science and Technology Letters. 2014;5(1):046-51.

48. Steyn NP, Mchiza Z, Hill J, Davids YD, Venter I, Hinrichsen E, et al. Nutritional contribution of street foods to the diet of people in developing countries: a systematic review. Public Health Nutrition. 2014;17(6):1363-74.

49. Staatz J, Hollinger F. West African food systems and changing consumer demands. OECD Publishing. 2016;4:1-26.

50. Alimi BA. Risk factors in street food practices in developing countries: A review. Food Science and Human Wellness. 2016;5(3):141-8.

51. Rezai G, Teng PK, Shamsudin MN, Mohamed Z, Stanton JL. Effect of perceptual differences on consumer purchase intention of natural functional food. Journal of Agribusiness in Developing and Emerging Economies. 2017;5:153-73.

52. Brunori A, Nobili C, Procacci S. Toward the Use of Buckwheat as an Ingredient for the Preparation of Functional Food. In: Zhou M, Kreft I, Woo SH, Chrungoo N, Wislander G, editors. Molecular breeding and nutritional aspects of buckwheat. Amsterdam, The Netherlands: Elsevier; 2016. p. 219-27.

53. Lim T. Curcuma longa. Edible Medicinal and Non-Medicinal Plants: Springer; 2016. p. 241-362.

54. Ogori AF, Amove J, Aduloju P, Sardo G, Okpala COR, Bono G, et al. Functional and Quality Characteristics of Ginger, Pineapple, and Turmeric Juice Mix as Influenced by Blend Variations. Foods. 2021;10(3):525.

55. Singh R, Feroze S, Kumar S. Production of Turmeric in North East Hill Region of India: A Value Chain Analysis. Indian Journal of Agricultural Economics. 2020;75(4):359-74.

56. Hay E, Lucariello A, Contieri M, Esposito T, De Luca A, Guerra G, et al. Therapeutic effects of turmeric in several diseases: An overview. Chemico-biological Interactions. 2019;310:108729.

57. Olojede A, Iluebbey P, Dixon A. IITA/NRCRI Collaborative Germplasm and data collection on minor Root and Tuber Crops in Nigeria. Annual Report. 2005:77-81.

58. Osawaru M, Eholor R. Ethnotaxonomy and traditional use of turmeric (*Curcuma longa* L.) among some Nigerian tribes in South Edo State, Nigeria. Plant Archives. 2010;10(1):181-9.

59. Olife IC, Onwualu AP, Uchegbu KI, Jolaoso MA. Status assessment of spice resources in Nigeria. Journal of Biology, Agriculture and Healthcare. 2013;3(9):12-8.

60. Kifelew H, Bekele D, Yadesa L, Getu A, Getachew W, Hailemichael G, et al. Result of Turmeric Variety Trial in Ethiopia. International Journal of Research Studies in Agricultural Sciences. 2018;4(9):34-8.

61. Christine EA, Benjamin KK, Maxwell BGA, Kati-Coulibaly S. Study of the Knowledge of Turmeric (*Curcuma longa)* and Ginger (*Zingiber officinale)* in the Region of Daloa (Côte D'Ivoire). American Journal of Plant Sciences. 2021;12(9):1328-37.

62. Nwaekpe J, Anyaegbunam H, Okoye B, Asumugha G. Promotion of turmeric for the food/pharmaceutical industry in Nigeria. Journal of Experimental Agriculture International. 2015;8(6):335-41.

63. Okechukwu AC, Adeyemi OO, Chinedu E, Peggy OC, Chukwuma NC. Multi-location Evaluation of Turmeric Genotypes in Nigeria. Journal of Agricultural Science and Technology B. 2013;3:842-6.

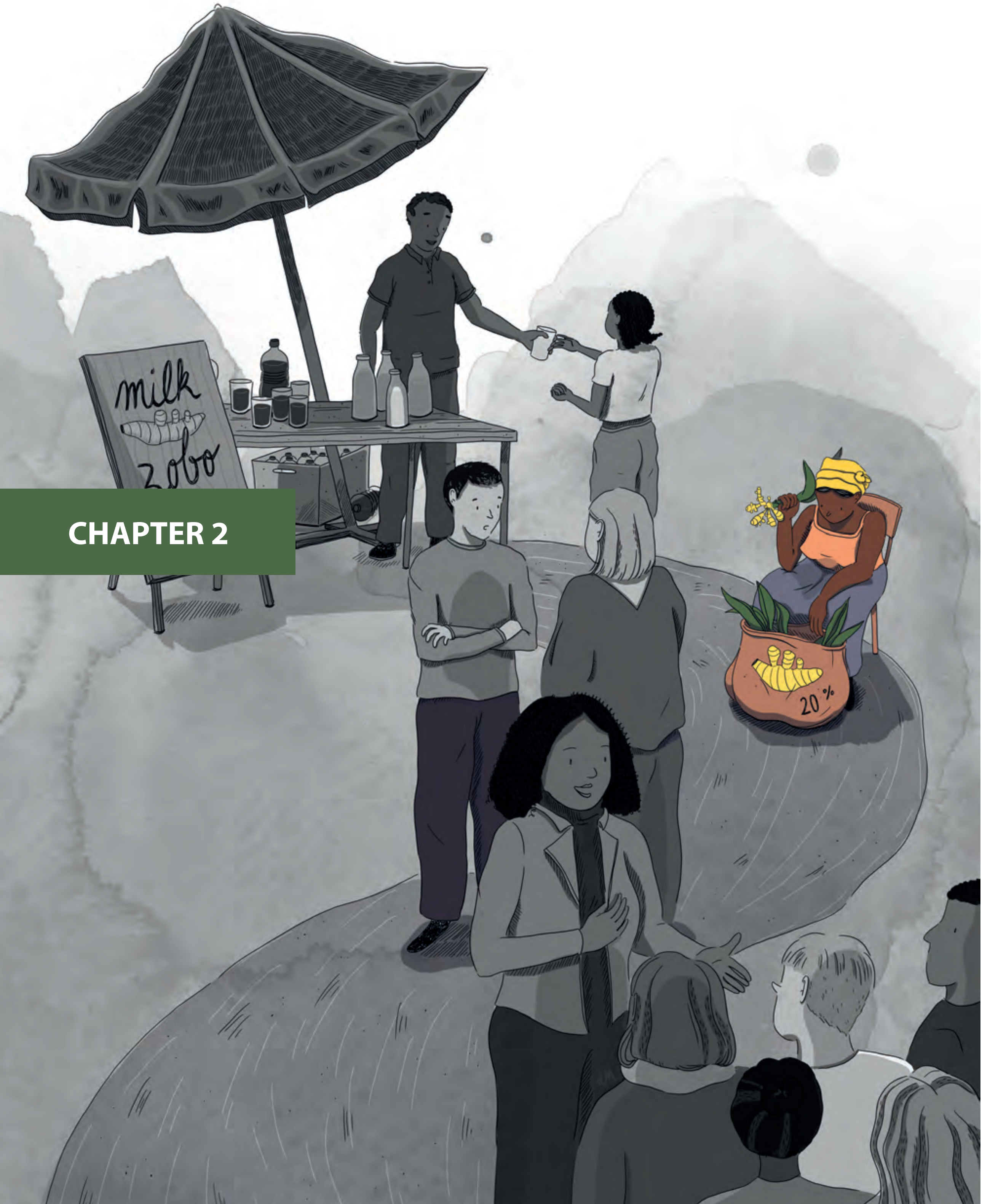
64. Muogbo P, Gbabo A, Nwakuba N, Onyekwere I, Obasa P. Livelihood Enhancement through Mechanization of Turmeric Production in Nigeria. In Proceedings of the 3rd NIAE-SE Regional Conference, University of Nigeria, Nsukka. 2018;27–30 August 2018:494-504.

65. Amadi C, Olojede O, Nwokocha C, Ironkwe A, Ohiaeri C, Amadi G, et al. Turmeric research at NRCRI Umudike: highlight of major achievements. Nigeria Agricultural Journal. 2018;49(1):57-64.

66. Chinedum E, Kate E, Sonia C, Ironkwe A, Andrew I. Polyphenolic composition and antioxidant activities of 6 new turmeric (*Curcuma longa* L.) accessions. Recent Patents on Food, Nutrition & Agriculture. 2015;7(1):22-7.

67. Etudaiye HA, Ukpabi UJ, Chukwuma S, Olojede OA. Possible short term storage effect on some chemical properties of locally processed turmeric powder in South-eastern Nigeria. Asian Journal of Plant Science and Research. 2015;5(7):6-12.

CHAPTER 2



Consumers' appreciation of turmeric (*Curcumalonga*) as a food ingredient – A review assessing options for new applications

The extended abstract of this chapter has been published as:
Idowu-Adebayo Folake, Oluwamukomi, Matthew O, Nana Adeyemisi H, and Linnemann, Anita R (2020). Consumers' perception on introducing a new ingredient in food- the case of turmeric (*Curcuma longa*). *Conference proceeding of the 44th Nigerian Institute of Food Science and Technology* (NIFST). AB080:201-202

Full chapter has been submitted for publication

Abstract

Globally, turmeric (*Curcuma longa*) is increasingly popular for its acclaimed health-supporting properties. However, introducing new ingredients into foods generally affects quality such as sensory attributes. To date, the consumer appreciation of novel foods with added turmeric has been studied in different countries but no meta-analysis has been performed yet. This study critically reviewed 53 articles on this topic. Data showed that the possibility to incorporate turmeric in food depends on the type of food. Turmeric was more preferred in snacks, pastry, beverages, and soups because its pungency and bitter taste were more noticeable when combined with meat and dairy products. Overall, up to 0.3% w/w, 1% v/v, 5% w/w, 6% w/w, 10% v/v, and 20% w/v turmeric can be added to meat, dairy, snacks, pastry, beverages, and soups, respectively, without affecting the sensory acceptability. Thus, a sizeable increase in the intake of turmeric as a food ingredient requires the selection of the right food that is tailored to the local consumer preferences.

Keywords: well-being, sensory, health, dietary intake, perception, SDG, Nigeria

2.1 Introduction

New food product development is a daily business in the global food industry as companies must constantly innovate to maintain their market position.[1] Technological innovations and advances in scientific knowledge may also prompt companies to develop new food products for their customers. Other reasons that instigate new food product development are changing societal needs, for instance, due to ageing populations, and changes in consumer perception, for example, consumer preferences for natural antioxidants.[2, 3] Antioxidants are utilised as food additives to preserve foods against oxidative degradation. To date, synthetic antioxidants like BHA, BHT, and TBHQ have long been employed to keep food products fresh. Since concerns have been expressed about their potential harmful and carcinogenic effects on humans and animals, the usage of these antioxidants has been questioned.[4] Consumers' attention has thus switched to natural antioxidants, which are thought to be safer than synthetic antioxidants. These natural antioxidants, particularly those derived from plants, have a significant potential for improving the foods' stability, shelf-life, palatability, and acceptability among consumers. Turmeric (*Curcuma longa*) is one such plant that has been utilised as a natural antioxidant in various foods.[3-8]

In accomplishing Sustainable Development Goals (SDGs), governments can opt to stimulate new food product development, thereby aiming to promote the sales and consumption of particular agricultural commodities. This situation is topical for turmeric in Nigeria where National Roots Crops Research Institute in Umudike and its regional research locations are testing turmeric accessions for release to farmers to boost their production and thereby their incomes.[9] Turmeric is a perennial herb belonging to the ginger family, *Zingiberaceae*. The Arabic root word, '*Kurkum*', seems the source of the Latin word for turmeric, i.e. *Curcuma.*[10] Turmeric is a plant that has been propagated vegetatively for thousands of years. Turmeric possesses a characteristic natural yellow colour that might have attracted human attention from the beginning of humankind. It is assumed to have originated on the mountain slopes in the tropical forests of the west coast of South India.[10] As many as 133 turmeric varieties have been identified worldwide.[11]

Turmeric is not a new crop in Nigeria. It reached East Africa in 800 AD and then spread to West Africa in 1200 AD.[12] It is recognized by different names that are subject to the locality, ethnic group and dialect in Nigeria. Turmeric is known as *atale pupa* in the South-West region, and *gangamau*, *turi* and *magina* in Northern Nigeria. In the South-East, South-South and North-Central Nigeria, the Ebonyi, Enugu, Tiv, and Cross River (Meo) ethnic groups call it *nwandumo*, *ohubobochi*, *gigir* and *onjonigho*.[13, 14] From an agronomic point, the promotion of the cultivation of turmeric is attractive as the crop is not very demanding. The plant grows at sea level up to a height of 1500 m on sandy, clay and loamy soils with temperatures between 20-30°C and a yearly rainfall of about 1500 mm.[13] Turmeric can be harvested throughout the year, making its use and sales very flexible.

Turmeric plays a prominent role in traditional medication practices.[15] Turmeric has been an Assyrian herbal remedy since 600 BC.[10, 16] The Chinese and Ayurveda devised a wide use of turmeric for hundreds of years to cure numerous inflammatory ailments.[15] according to the quote of an Ayurvedic scholar "If I had a single herb to depend upon for all possible health and dietary needs, I would without much hesitation choose the Indian spice turmeric." Dr. David Frawley. In addition, the earliest Greek physicians, and practitioners of naturopathy, which is nowadays applied in several countries including Australia, Canada, the United Kingdom, the United States and New Zealand, advocate an appropriate diet as the best way to treat a disease. Intervention in the patient’s nutritional habits forms part of their treatment methods, and the number of people who trust this approach is increasing across the continents.[15, 17-19]

Turmeric has several beneficial traits, from the treatment of wounds and common colds to chronic diseases.[20, 21] Various health-supporting properties are attributed to turmeric: antioxidant, antiviral, anti-infectious, anti-tumour, anti-metastatic, anti-proliferative, anti-inflammatory, anti-hepatotoxic, anti-venom, and anti-protozoal effects with potential activity against HIV/AIDS, cancer, arthritis and Alzheimer’s disease.[5, 22, 23] Turmeric has been shown to lessen the risk of childhood leukaemia and reduce the progression of multiple sclerosis.[24] It is a natural liver detoxifier as well as an efficient pain reliever.[21] Turmeric intake offers therapeutic and nutritional properties and is safe when taken at the recommended dosage.[24-26] Aside from being food, turmeric is a commercially approved additive in the USA, used as a colourant in various prescribed drugs, yellow mustards and cosmetics. Turmeric is an accepted natural colourant worldwide.[21, 27] Dishes prepared with turmeric typically have a yellow colour and a pungent taste. Consumer appreciation of novel foods with turmeric as an ingredient has been studied for different foods in different countries. This study critically reviews how consumers globally respond to turmeric in nutrition to assess the most suitable foods to develop to stimulate sales and consumption of turmeric. We determined the optimal food matrices with the quantity of turmeric consumers liked best and, more generally, we designed an approach towards promoting new food ingredients.

2.2 Methodological approach

A comprehensive literature search was conducted on three databases, namely Scopus, Web of Science and Google Scholar, from November 2018 to July 2019. The series of search terminology were formulated based on our review topic of interest. The search terminology only targeted titles, keywords and abstracts.[28] The search terms were: 'turmeric production', 'uses of turmeric', 'turmeric awareness and growth in Nigeria', 'turmeric fortified foods', 'turmeric food acceptability', 'turmeric food consumption', 'turmeric added to food', 'overall acceptability of turmeric added to food' and 'consumer acceptability of turmeric fortified food'. Overall, "the acceptability of turmeric added to food" yielded 2600 articles on Google Scholar. Therefore, we restricted the search year limit for this database to articles published from 2010 onwards. We sorted by relevance to our search terminology; patents and citations were excluded. The sorting reduced the number of articles to 1040. There was no search year limit for the Scopus and Web of Science databases as well as no restriction regarding publication language.[29] The literature search was updated between September and October 2019 using the reference manager software Harzing's Publish or Perish 7 to search the three earlier databases with the inclusion of Crossref as the fourth database.[30]

The articles were compiled in an Excel table in Endnote and Harzing's Publish or Perish 7 for analysis. Duplicated records were first discarded with the conditional formatting command in Excel to highlight the duplicate values. The remaining articles were later subjected to statistical software XLSTAT to confirm the removal of duplicate records.[29-31] Our initial dataset comprised 433 articles. The titles, keywords, abstracts, and results of these articles were read and manually sorted to remove further articles that did not fit our review aims. At this stage, our focus was on the studies on the inclusion of turmeric in food and consumer appreciation of turmeric-fortified foods. Therefore, articles in which turmeric addition (i.e., amount of turmeric included as part of the food ingredients) were not mentioned, or the effect of adding turmeric was not part of the objective, were discarded. Articles using advanced technologies such as nano-emulsion and encapsulation of turmeric extract as an ingredient were also discarded because these were beyond our scope. The exclusion of these articles was to limit our findings to simple and locally affordable technologies for adding turmeric to foods that local processors in developing nations can use effectively. Articles on the preservative effect of turmeric with results on the overall acceptability of turmeric as a natural antioxidant in processed food were included. Finally, journals without an English interpretation were discarded. After applying the inclusion/exclusion criteria, a total of 53 articles remained for the final analysis.

2.3 Turmeric-fortified foods

The scientific interest in the turmeric root is reflected in the number of research publications on turmeric which increased by a factor of ten from 1995 to 2009, and almost doubled from 2014 to 2019 (Fig. 2.1). The increase in the number of articles also corresponds to the increasing awareness of the health benefits of turmeric to consumers.[27] Traditionally, turmeric is a principal spice of Indian cuisine, but in recent years it has found many applications in dairy, pastries, snacks, fruits and vegetable sectors of food industries in many other countries across the globe, as presented in Table 2.1. The addition of turmeric to various foods and beverages might be explained by the high demand of food companies for products that meet the needs and demands of consumers for a healthy lifestyle, in which foods enriched with functional plant ingredients play a crucial part.

Dairy products

Herbal milk: Gaur et al.[32] developed herbal milk by adding turmeric to other medicinal plants, namely, tulsi (*Ocimum tenuiflorum*) and ginger (*Zingiber officinale*) juice in India (Table 2.1). Different ingredient formulations were presented to consumer panellists for evaluation on colour, general appearance, sweetness, consistency, flavour, and overall acceptability.

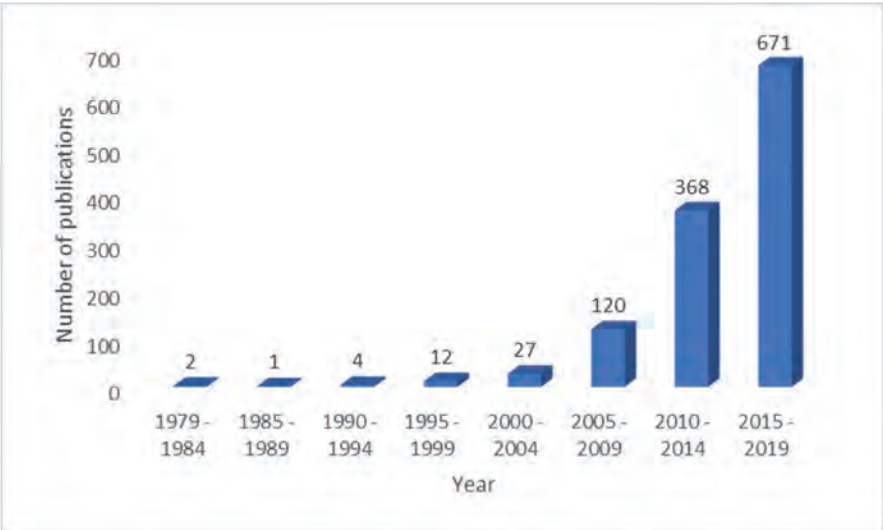


Figure 2.1: The number of publications on turmeric studies from 1980 to 2019

Table 2.1: Studies on the addition of turmeric to foods and beverages

Product, country	Ingredient(s) and formulation	Type of sensory test	Findings	Reference(s)
Dairy				
Herbal milk, India	Tulsi juice (25%), ginger juice (3%), turmeric powder (0.1 to 1.0% w/v).	A nine-point Hedonic scale was used with seven assessors acquainted with dairy products who were regularly active in sensory evaluation.	The addition of 0.1% w/v turmeric powder improves the colour/appearance and flavour greatly ($p < 0.05$). The ratings for 0.2 to 1% turmeric powder dropped due to excessive bitterness and increased turmeric powder sediments. Overall acceptability followed a similar pattern.	[32]
Paneer prepared from different types of milk, India	0.2 to 1.0% turmeric powder by weight of likely yield of paneer.	A nine-point hedonic scale using a group of semi-trained panellists.	When turmeric was added to paneer at a percentage greater than 0.6% w/w, the sensory scores for colour, flavour, texture, and overall acceptability of paneer made from cow milk, buffalo milk, or mixed milk were reduced significantly.	[35, 46]
Cottage cheese, India	Addition of 0.5 to 2% w/v turmeric powder to cottage cheese prepared from skimmed milk.	A nine-point hedonic test.	The cottage cheese with a concentration of 0.5% turmeric powder had the highest general acceptance.	[33]
Yoghurt, Egypt	Set-yoghurt was prepared from buffalo's milk supplemented with turmeric powder of 0 to 1% (w/v).	A nine-point hedonic and descriptive study was used to express the preferences of two consumer groups. Group-I consisted of 50 consumers from the local region, whereas group-II consisted of 50 consumers chosen randomly from various Cairo districts.	Adding turmeric powder as a medicinal plant to dairy products like yoghurt was a great idea by 90% of Egyptians. The two groups preferred a lower amount of turmeric (0.1%), which also enhanced several rheological qualities of set-yoghurt.	[34]
Lassi (India's popular fermented dairy beverage), India	Addition of 0 to 4% v/v turmeric juice.	A nine-point Hedonic scale using five trained judges.	The *lassi* with turmeric juice added at 1% (v/v) was ranked the best for all the sensory parameters.	[47]

Table 2.1: (continued)

Product, country	Ingredient(s) and formulation	Type of sensory test	Findings	Reference(s)
Pastry				
Bread, Korea	0 to 8% w/w turmeric powder substitution levels in wheat flour.	A nine-point hedonic test was conducted with 80 untrained consumers who were told they would be testing bread samples beforehand.	The taste and overall acceptance of wheat flour replaced with 2 to 4% turmeric powder in bread were satisfactory. There was no statistically significant variation in aroma and texture across all samples (from 0 to 8%).	[5]
Bread, Pakistan	0 to 4% w/w turmeric powder incorporated into bread dough formulation.		In their findings, adding 3% turmeric to bread flour positively affected all sensory qualities and was rated as the best treatment. However, adding up to 4% Turmeric to the bread has no noticeable influence on the flavour or texture.	[37]
Cake, Korea	0 to 8% w/w of turmeric powder added in corresponding wheat flour grams.	The degree of texture and general acceptance was measured using a nine-point hedonic scale with 80 panellists.	There was no statistically significant difference in texture acceptability amongst the samples. While there was a substantial difference in overall acceptability from 0% to 6% turmeric cakes.	[27]
Biscuit, Nigeria	0.5 to 1.0 g turmeric powder and 10 to 29.5 g of soybean flour as a wheat flour substitute.	The sensory properties of the biscuits were measured using a nine-point hedonic scale with 20 panellists.	There was a noticeable variation in colour between the control and fortified biscuits. The biscuits manufactured using fortified-wheat flour, on the other hand, had no evident change in overall acceptance.	[7]

Table 2.1: (continued)

Product, country	Ingredient(s) and formulation	Type of sensory test	Findings	Reference(s)
Beverage and jam				
Turmeric- Orange RTS beverage, India	The ratios of orange juice to fresh turmeric rhizome juice were 100:0, 95:05, 90:10 and 85:15.	A nine-point hedonic scale by ten semi-trained judges.	All sensory attributes such as colour, flavour, general acceptability, and taste were preferable when the 90:10 ratio was used.	[41, 42]
Turmeric-carrot jam, Egypt	Addition of turmeric powder with (0, 0.2, 0.4, and 0.6% w/w carrot)	A nine-point hedonic scale using 15 untrained jam consumers.	Turmeric powder, up to 4% w/w raw carrot, could be added to the jam formulation to increase its quality without producing any sensory defects.	[43]
Soup				
Lentil soup, Egypt	0 to 3% w/w of lentil seed weight.	A nine-point hedonic scale using 20 trained panellists.	Turmeric powder, up to 2% lentil seed, could be added to lentil soup ingredients to increase the quality features without sensory defects.	[44]
Turmeric soup, India	Addition of 0 to 30 % w/v turmeric paste in the soup.	A nine-point hedonic.	The highest overall acceptance score was recorded with the addition of 20% turmeric paste.	[45]

Table 2.1: (continued)

Product, country	Ingredient(s) and formulation	Type of sensory test	Findings	Reference(s)
Snacks				
Snacks, Nigeria	For plantain: bambara: turmeric ratio, the turmeric value was kept constant at the ratio of five in the ingredient mix.	A nine-point hedonic using thirty experienced snack consumers.	Unripe plantain, bambara nut, and turmeric flour were combined to produce snacks with increased sensory quality. This combination will reduce the usage of wheat flour in snack production in Nigeria while also increasing the exploitation of turmeric, bambara nut, and plantain, and preventing underutilisation.	[40]
Egg tofu, Malaysia	0.1 to 1.0% w/w turmeric powder.	Thirty panellists used a seven-point hedonic scale.	Herbal egg tofu comprising 0.7% pigmy knotweed, 0.5% turmeric and 0.8% ginger had the optimum formulation with colour, taste and overall acceptability.	[39]
Kokoro (maize-based fried/baked snacks), Nigeria	*Kokoro* was produced from various blends by fortifying maize flour containing Fibersol 2 and whey protein with 1% w/w each of the functional ingredients; ginger, red paprika, fenugreek, spirulina and turmeric.	A nine-point hedonic preference scale and multiple comparison tests by thirty panellists.	The overall acceptability means the sensory score of turmeric spiced *kokoro* was not statistically significantly different from the score of fenugreek spiced *kokoro*.	[38]
Yukwa (rice-based fried snacks), Korea	Addition of turmeric powder 0 - 10 g / 100 g waxy rice flour.	A seven-point hedonic scale using 25 panellists.	The inclusion of 5% turmeric powder had the highest overall acceptability for *yukwa* preparation.	[23]

2

Table 2.1: (continued)

Product, country	Ingredient(s) and formulation	Type of sensory test	Findings	Reference(s)
Meat and fish products				
Beef meatballs, Bangladesh	0.1 to 0.3% w/w of turmeric powder added to fresh beef before shaping, boiling and frying	Eight trained panellists used sensory questionnaires to quantify intensity on a five-point balanced semantic scale for the sensory qualities.	In terms of flavour, colour, tenderness, juiciness, softness, and general acceptability, 0.3% turmeric powder was the most preferred.	[4]
Cuttlefish (*Sepia brevimana*), India	For thirty minutes, the cuttlefish has dipped in 0.5% (w/v) solution turmeric (rhizomes of turmeric powdered and diluted with triple-deionized water).	Quality Index Method (QIM) scored as high quality (0), good quality (1), fair quality (2) and unacceptable quality (3) by five panellists were used for the sensory analysis. Samples were unacceptable when reaching a total score higher than 12 (scale of 0 to 17).	Overall sensory evaluation got rejection QIM scores (13.4) on day 15, indicating that dipping cuttlefish in turmeric solution was highly effective in delaying spoilage indices and extending the shelf life of *S. brevimana* by three days when compared to cuttlefishes kept at the same four °C but not treated with turmeric, which had a QIM score of (14.1) on day 12.	[8]

The values of the sensory rates of the herbal milk differed significantly, with 0.1% w/v turmeric powder providing the best results. Due to high sedimentation and a bitter taste of turmeric that the panellists disliked, the scores for herbal milk with 0.2% w/v turmeric powder dropped. A similar trend was observed in overall acceptability. Gaur et al.[32] concluded that the optimum amounts of turmeric powder, tulsi, and ginger juice in herbal milk were 0.1%, 25%, and 3%, respectively. The addition of these ingredients to milk gives a distinctive flavour, thereby improving the sensory quality and acceptability of the product.

Cottage cheese: Kishor and David[33] added turmeric, chickpea (*Cicer arietinum*) and black pepper (*Piper nigrum*) to cottage cheese in India (Table 2.1). Several concentrations (% w/v) of turmeric powder (0.5, 1, 1.5 & 2) and chickpea milk (20, 30, 40 & 50) with black pepper (0.2) were added to skimmed milk for the cottage cheese preparation. Sensory panellists assessed the colour, flavour, texture, taste and overall acceptability of the best out of the 17 different treatment combinations used in the study. The sensory score for cottage cheese made from 0.5% turmeric powder, 20% chickpea milk, and 0.2% black pepper was the best for colour, texture, flavour, and overall acceptability. All the sensory parameter scores decreased with an increase in turmeric and chickpea concentrations.

Yoghurt: Foda et al.[34] evaluated yoghurt enhanced with turmeric. Turmeric powder (0, 0.1, 0.25, 0.5, 0.75 and 1% w/v) was added to yoghurt and tested for appearance, flavour and texture by judges who were familiar with the product. A preference test on the turmeric-fortified yoghurt was also conducted with consumers from Egypt's rural and urban areas (Table 2.1). Furthermore, consumers' opinions on the idea of adding medicinal herbs, like turmeric powder, to yoghurt were explored in the study. By increasing turmeric concentrations to 0.5%, appearance scores declined, although not significantly, and then decreased significantly with 0.75 and 1% turmeric. The observation was attributed to the condensed yellow colour, which influenced the experienced judges' assessment of the highest concentrations of turmeric in yoghurt.

Besides, due to the intense flavour and increased yoghurt's acidity by adding more turmeric, concentrations above 0.25% got lower scores for flavour from the judges. The highest turmeric concentrations also resulted in a substantial decrease in mean scores for texture. Low turmeric (0.1%) concentration received the best mean score for preference from the consumers' groups, which decreased significantly as turmeric concentrations increased. Turmeric-fortified yoghurt was rated as an excellent concept by 90% of the participants regarding the proposition of adding medicinal herbs to yoghurt. Ten per cent thought the proposal was a good idea, and no one thought it was poor. Foda et al.[34] concluded that using a small amount of turmeric improved both the consumer acceptability and the rheological qualities of yoghurt.

Paneer: As shown in Table 2.1, Singh et al. and Buch et al.[2, 35] reported the impact of turmeric addition on the sensory properties of paneer, a typical Indian-style cottage cheese. In the latter study, turmeric was added at 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0% by weight of projected paneer yield. Samples were evaluated for flavour, texture, colour and overall acceptability. The former research used 0.0 - 0.6% and milk from different animal sources (cow, buffalo, and a mix of both). Buch et al.[2] selected 0.4% (w/w) turmeric in paneer because at higher amounts they observed a sharp decline in the paneer's colour and flavour scores. Singh et al.[35] concluded that adding turmeric to paneer made from cow, buffalo, and mixed milk at a rate larger than 0.6% w/w resulted in a significant decrease in sensory scores and texture, although the products were still acceptable and safe to eat.

Lassi: Lassi is one of India's most popular fermented dairy beverages, made by churning curd. Maji et al.[36] fortified *lassi* with different natural ingredients, namely carrot, ginger, and turmeric. The juice produced from these crops was added to *lassi*, and the effect of varying levels (v/v) of each extract on sensory qualities was tested. The mean colour score in turmeric-fortified *lassi* decreased, but not significantly, after increasing the concentration up to 2% and subsequently decreased significantly up to 4%, owing to the alteration of the colour of *lassi* to bright yellow. The overall acceptability score of the *lassi* containing 1% turmeric extract was the highest (Table 2.1). The ratings began to drop significantly with larger doses. The mean scores for colour, flavour, texture, and overall acceptability were high in *lassi* containing 15% v/v carrot juice in comparison with *lassi* containing 10, 20, and 25% carrot juice. The mean scores for colour and texture declined for ginger-fortified *lassi*, but not significantly, up to a concentration of 2% and then sharply up to 4%. When compared to the other herbal *lassis*, turmeric-fortified *lassi* got the highest overall sensory score.

Pastry

Bread: Lim et al.[5] proposed that turmeric-fortified bread could be developed as a health-promoting functional food in their study on the nutritional value and antioxidant effects of South Korean turmeric in bread. Muhammad et al.[37] also proposed incorporating ginger and turmeric into the bread dough formulation in Pakistan. No significant variation was found in the texture of samples up to 8% (w/w) substitution of wheat by turmeric powder in the bread dough formulation. Additionally, a 2% (w/w) turmeric powder substitution did not affect the natural colour of the wheat bread. The crumb colour of bread containing 8% (w/w) turmeric powder, on the other hand, received the lowest score for liking. Bread with turmeric powder at 0–4% substitution levels received the highest scores for taste, flavour, and overall acceptance.[5] However, due to significant amounts of volatiles and phenolic chemicals, which were not appreciated, bread with 6 and 8% turmeric had the lowest scores. According to the liking results and overall customer acceptability, a partial substitution of wheat flour with up to 4% turmeric powder in bread was considered to be achievable[5, 37] (Table 2.1).

<u>Cake</u>: The effects of adding turmeric powder (0, 2, 4, 6, and 8% w/w) to wheat flour dough to achieve an antioxidant-rich cake with good sensory characteristics have been reported,[6] see Table 2.1. The hardness of the cake decreased with increasing amounts of turmeric powder. Nonetheless, no significant differences in texture acceptability were noted across the samples. Apparently, the hardness of the cake did not affect consumer acceptability when turmeric was used to substitute wheat flour up to 8% w/w. Furthermore, the cake with the highest amount of turmeric powder (8%) had the highest antioxidant properties. Still, as for bread with high substitution levels of wheat flour by turmeric powder,[5] this cake sample was not acceptable due to excessive amounts of volatiles and phenolic compounds that negatively affected the sensory evaluation of the taste. The cakes with turmeric powder at substitution amounts of 0–6% w/w had the highest overall acceptance score. Consequently, a turmeric powder replacement level of up to 6% could be used in a cake formulation without affecting the cake's sensory acceptability.[6]

<u>Biscuit</u>: In Nigeria, Adegoke et al.[7] aimed at producing a functional food made of wheat flour, soya bean, and turmeric (Table 2.1). They recommended the optimum composite flour blends (w/w) for biscuit production as 72.9%, 26.6%, and 0.5% of wheat flour, soya bean flour, and turmeric powder, respectively, for the appropriate use of turmeric as a functional food ingredient in biscuit production. Turmeric incorporation into the biscuits enhanced their nutritional quality while also improving colour and other sensory features, as well as overall acceptability.[7]

Meat and fish

<u>Meatballs</u>: The impact of varying doses of turmeric powder and synthetic antioxidants on the sensory quality of fresh beef meatballs and as a source of value-addition to meat products has also been investigated in Bangladesh.[4] Control, synthetic antioxidant (BHA) and turmeric powder as a natural antioxidant (0.1, 0.2, and 0.3% w/w) were used in producing ground beef. Sensory evaluation of the fried meatball samples rated the 0.3% turmeric powder sample the

best in terms of flavour, colour, softness, juiciness, and overall acceptability among the treatments (Table 2.1). Meatballs with 0.3% turmeric powder were thus established as a value-added product full of natural antioxidants.[4]

Cuttlefish (*Sepia brevimana*): Cuttlefish treated with turmeric extract had delayed spoilage and extended shelf life. The sensory analysis was conducted using the Quality Index Method (Table 2.1). Overall sensory assessment reached rejection QIM scores (13.4) on day 15, signifying that dipping cuttlefish in a turmeric solution was highly effective in delaying spoilage. The shelf life of cuttlefish could also be extended by three days when stored at the same 4°C but not treated with turmeric, which had a QIM score of 14.1 on day 12. According to the sensory evaluation, the 0.5% (w/v) turmeric coating increased the shelf life of cuttlefish muscle without changing its appearance, flavour, or texture up to day 15 of storage at 4°C.[8]

Snacks

Kokoro: *Kokoro*, a maize-based street-vended snack, is popular among Nigerians. Different *kokoro* mixtures were made by fortifying a maize flour-Fibersol 2-whey protein blend with 1% w/w of various functional components, namely spirulina, fenugreek, ginger, red paprika and turmeric (Table 2.1). Another mix comprising all these components was also prepared at 1% each. The control sample was a mixture of maize flour with Fibersol 2 and whey protein powder (98% maize flour: 1% whey protein powder: 1% Fibersol 2). All samples were evaluated for appearance, taste, texture, aroma, and overall acceptability. The control's sensory parameters and the maize-whey protein-spices-based *kokoro* snacks were significantly different.

The panellists preferred the red-paprika-spiced *kokoro* blend. This was followed by the ginger-spiced *kokoro* sample and the turmeric- and fenugreek-spiced *kokoro* snacks. For all the sensory features examined, the all ingredients-based *kokoro* was the least liked. Adding turmeric to familiar foods is new in most countries, and red paprika is an essential and fundamental ingredient in regular meals. Adding a familiar ingredient to *kokoro* could thus explain why the red paprika-spiced *kokoro* blend had the highest mean sensory score and overall acceptability.[38]

Egg tofu: In Malaysia, Maizura et al.[39] optimized the herbal egg tofu ingredients comprising pigmy knotweed (*Polygonum minus*), turmeric, and ginger (Table 2.1). Consumers' preferences on colour, texture, taste, and overall acceptability of the herbal tofu were examined. Herbs and spices contain polyphenolic chemicals that can generate pungency, spiciness, bitter taste and astringency when added to food.[5, 6] The panellists' responses to the sensory features of herbal egg tofu were impacted when pigmy knotweed, turmeric and ginger were added in large amounts. Blends (w/w) of 0.7% pigmy knotweed, 0.5% turmeric and 0.8% ginger yielded the best egg tofu formulation. Turmeric was the main ingredient contributing to herbal egg tofu's increased antioxidant activity.[4, 7, 8] Incorporating turmeric into egg tofu with enhanced antioxidant activity also provides aroma, colour, and taste that make tofu more appealing. As a result, consumers can boost their natural antioxidant intake by eating turmeric-fortified egg tofu.[39]

Turmeric-fortified rice snack: *Yukwa,* a traditionally fried waxy rice snack, is the most preferred Korean commercial snack regarding consumers' sensory preferences, with texture and flavour created through the deep fat frying method.[23] Turmeric powder (0, 2, 5, 8, and 10% w/w) was added to the waxy rice flour (Table 2.1). For appearance, flavour, taste, texture, and overall acceptance, the sensory properties of *yukwa* with various concentrations of turmeric powder were tested. Although all the turmeric-fortified *yukwa* samples had a distinct colour connecting to the amount of turmeric powder used, the sensory assessors' choice for appearance was not significantly different for all samples. Also, the flavour of *yukwa* did not change as the amount of turmeric powder increased. Moreover, there was no difference in texture or taste between the 0% and those containing up to 5% w/w turmeric powder. However, due to the bitter taste of turmeric, above 8% addition of turmeric powder considerably affected the taste preference of *yukwa*. There was also a fall in texture preference and overall acceptability at this high level of turmeric. As a result of the sensory test, adding up to 5% turmeric powder in *yukwa* was found to be acceptable.[23]

Turmeric-plantain–bambara nut snack: Unripe plantains, bambara nuts, and turmeric were processed to flour and mixed in varying ratios: 100:0:0, 60:35:5, 50:45:5, 45:50:5, 35:60:5, 0:100:0, respectively. The consumer acceptance of a snack made from these composite blends was tested in Nigeria (Table 2.1). The addition of bambara nut flour improved the snack's taste. Except for colour and aroma, 100% bambara nut had the highest scores in most of the sensory attributes, while 60:35:5 had the lowest scores in all of them. There was no significant difference in crispness between all snack samples, nor in aroma or colour between samples composed of 35:60:5 and 60:35:5 unripe plantain. Still, there was a significant difference in texture, taste, and overall acceptability. Moreover, overall snack acceptance increased with an increase in bambara nut flour and a decrease in unripe plantain flour. As a result, 35:60:5 had the greatest overall acceptability scores and was recommended for snack production.[40]

Beverage and jam

Turmeric-orange ready-to-serve beverage: Combinations of 95:05, 90:10, and 85:15 orange juice: fresh turmeric rhizome extract were produced in India (Table 2.1). The prepared Ready-To-Serve (RTS) turmeric-fortified orange beverages were tested for flavour, taste, colour, and overall acceptability. In terms of colour, flavour, and taste, samples containing 5 and 10% v/v turmeric were statistically similar, except for overall acceptance. When panel members' evaluations were compared, it was apparent that the turmeric-orange beverage's colour depended on the amount of turmeric juice used. However, the 15% turmeric-fortified orange beverage sample scores lower than all other samples. This is due to the noticeably darkened colour and appearance of the sample. Overall, the highest colour and sensory attributes scores were found in 10% turmeric, followed by 5 and 15% turmeric-fortified orange beverage.[41, 42]

Turmeric-carrot jam: In Egypt, a turmeric-carrot jam produced from turmeric powder (0, 0.2, 0.4, and 0.6% w/w) was tested for odour, colour, texture, taste and overall acceptability [43] (Table 2.1). In terms of colour, there was no significant difference between all turmeric-carrot jams, but the control had a much lower colour score. This could be linked to the fortification with turmeric, which also served as a colouring ingredient. In terms of texture, all the turmeric-carrot jams samples were valued, with no significant differences. Due to the richness of turmeric in volatile compounds, which cause bitterness at the highest turmeric concentration, the samples with 0.2 and 0.4% turmeric were more preferred than the samples with 0 and 0.6% turmeric in terms of odour, taste and overall acceptability. Overall, turmeric powder, up to 0.4% w/w raw carrot, might be included in jam formulations to increase quality features without producing any sensory defects.

Soup

Turmeric-lentil soup: Traditional Egyptian lentil soups were made with turmeric powder at percentages (w/w) of 0, 1, 2, and 3% of the lentil seed weight[44] (Table 2.1). Trained panels rated the lentil soup on appearance, taste, flavour, texture attributes, and overall acceptability. The results show that adding turmeric powder to the soups significantly impacts all sensory qualities. The 1% and 2% scored significantly higher on all metrics than 3% and 0%. Moreover, increasing the quantity of turmeric powder added to lentil soup enhanced viscosity and colour while decreasing lightness. The results showed that adding 3% of turmeric to lentil soup had good overall acceptability by panellists, similar to the 0% turmeric sample. Still, the taste score was lowered compared to adding 1% and 2% turmeric to lentil soup. This could be because raising the amount of turmeric to 3% resulted in a bitter taste. Overall, turmeric powder, up to 2%, might be used in lentil soup formulations to increase quality features without generating any sensory defects.[44]

Turmeric soup: Pawar et al.[45] standardized the Indian turmeric soup preparation process using 10%, 20%, and 30% w/v turmeric (Table 2.1). The sensory qualities of the prepared soup were investigated. The sensory evaluation of turmeric soup was conducted by a semi-trained panel, with scores based on appearance, colour, flavour, taste, and overall acceptability, compared to a soup sample without the inclusion of turmeric paste. Across all testing, the soup sample without the addition of turmeric paste was determined to be statistically significant. Moreover, there were differences among all the soup samples prepared with turmeric paste. It was obvious from comparing panel members' evaluations that the appearance, colour and flavour of turmeric soup depended on the amount of turmeric paste added to the soup. Twenty per cent turmeric soup had the highest score, followed by 10 and 30%, which had low scores. The sample with 30% received the lowest score of all the samples due to a higher amount of turmeric paste in the sample, which caused the panel members to rank it lower in appearance, colour and flavour. A similar trend was found in taste and overall acceptability. The sample with 30% turmeric paste received the lowest score due to the astringency of the turmeric paste, which was considered undesirable by the panel. Overall, soup with 20% turmeric paste was the most acceptable among the soups containing turmeric.[45]

2.4 Promotion of new food ingredients

Introducing turmeric into food to produce novel health-supporting products may affect quality properties. This study shows that changes in sensory attributes such as colour, taste, aroma, flavour and textures can affect consumers' overall acceptability of such innovative food products.[48, 49] Especially the bitter taste of turmeric causes a significant decrease in the appreciation of turmeric-fortified foods when turmeric is added in high amounts. The current review further shows that consumers' taste preferences are also primarily related to the amount of turmeric added to food in relation to the food matrix.

Table 2.2 summarizes the studies on turmeric-fortified foods and their validated ingredient formulations. For instance, 4 and 6% w/w substitution of wheat flour with turmeric was appreciated by consumers in bread and cake, respectively.[5, 6, 37] However, in biscuits, 0.5% w/w turmeric powder was the optimum level in the composite flour comprised of wheat flour, soya bean flour and turmeric powder.[7] A similar trend was found in consumer appreciation of turmeric in snacks. Turmeric can be added up to 5% w/w in *yukwa* rice and snack produced from blends of turmeric-plantain-bambara nut flour.[23, 40] However, egg tofu blends with 0.5 % w/w turmeric yielded the best formulation.[39] Furthermore, turmeric can be added up to 20% in soup and still be acceptable to consumers [45]. Still, turmeric addition has to be as little as 0.3 to a maximum of 1.0% in meat and dairy products, respectively.[4, 32]

As turmeric is gaining more popularity globally, the government is currently promoting, the sales and consumption of turmeric in Africa especially, in Nigeria where turmeric is presently cultivated on a subsistence level[14, 50, 51] in 19 states (Fig. 2.2). The Nigerian government also created different economic empowerment programs at the national, state, and municipal levels in accordance with the Sustainable Development Goals. Such programmes include the Youth Entrepreneurship Support Programme (YES-Programme) and the Youth Entrepreneurship Development Programme (YEDP), of which both targeted beneficiaries are the National Youth Service Corps (NYSC) members. The latter included up to five years post-NYSC members and those who possess verifiable high school, technical school and tertiary institution certificates.

Table 2.2: Turmeric-fortified foods and validated ingredients

Food	Ingredients
Turmeric-rice snack	Turmeric powder 5 g /100 g waxy rice flour
Turmeric-soup	20% turmeric paste in the soup
Turmeric-carrot jam	Turmeric powder 4 g /1000 g carrot
Turmeric-beverage/drink	The ratios of 90:10 orange juice (for instance) to fresh turmeric rhizome juice
Turmeric-bread	Substitution of 4% turmeric to bread flour
Turmeric-meatball	Addition of 0.3% of turmeric powder to fresh meat before shaping, boiling and frying

Derived from[4, 23, 41, 43, 45]

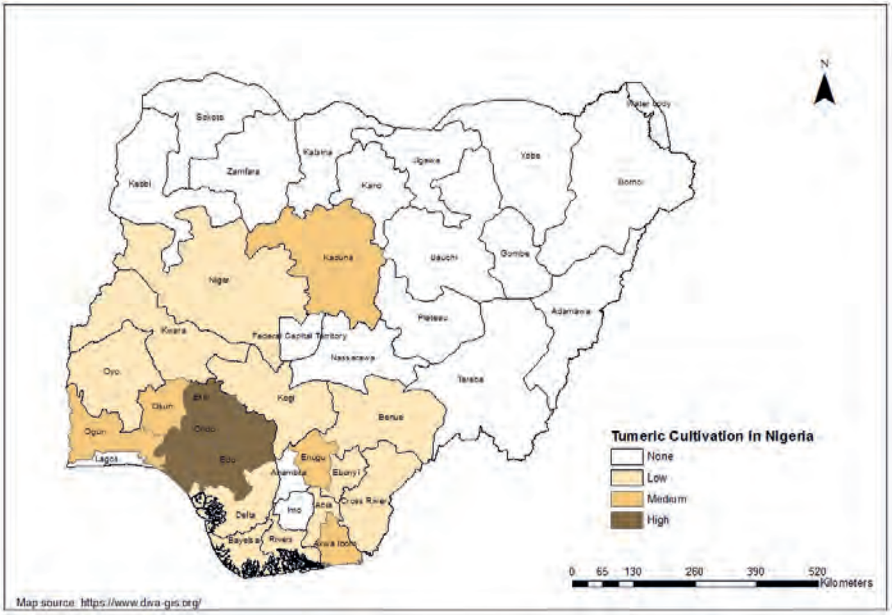


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Figure 2.2: Map of Nigeria showing the turmeric-producing states (adapted from Olojede et al.[14])

These programmes' activities involve financing startups in agricultural value chains, cottage industries, skill acquisition training etc. Thus, turmeric-fortified foods product development training could be included in schemes like the NYSC to promote self-employment among the youth. The acquired technical skills will also qualify them to be a beneficiary of these economic empowerment programmes. Additionally, further uses of turmeric as reported in the literature are shown in Figure 2.3 for the benefit of those whose interests are not limited to food and to demonstrate the ubiquitous uses of turmeric.

We found studies by researchers from Nigeria, the country targeted to improve the use of turmeric while conducting this review. Turmeric has been incorporated into street-vended foods like *kokoro* (maize-based fried snacks) and biscuits (Table 2.1). Consumers' appreciation of these foods demonstrated the potential of adding turmeric to other Nigerian staple foods like bread, *masa*, *beske*, and rice, street-vended beverages like *kunu*, *zobo*, *pito*, *burukutu*, and soya milk, and other suggested turmeric-fortified foods that are feasible to produce in Nigeria and other nations are presented in Table 2.2 as some of these street-vended foods and beverages are also known globally.

2

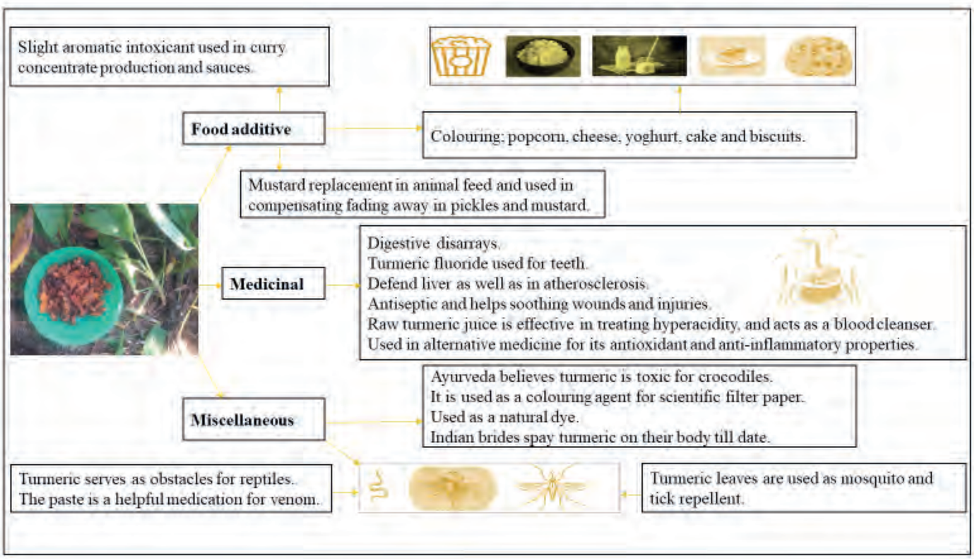

Figure 2.3: Uses of turmeric (sources [20, 24-26, 52, 53])

For instance, *zobo*, a popular Nigerian street-vended drink produced from *Hibiscus sabdariffa* calyces and optionally flavoured with garlic, ginger, or fruit is a global drink known as *dabileni, karkade, karkanji, wonjo zobo,* and *bissap* in other parts of Africa. In Asia, the beverage is known as *asam belanda, mei gui qie*, Indian sorrel, *ribena*, *karkade*, and *krajeap* among other local names. In Australia, it is known as rosella, and in Mexico, as *flor de Jamaica*. In Europe, *zobo* is known as *Congo*, *Jamaica* and *karkade*. Likewise, soya milk is consumed across the globe. Allergies, increases in protein demand and the dairy industry's sustainability challenge have contributed to increased consumption of soya milk. Consumer demand for healthy, ethically produced and sustainable meals could thus make the promotion of turmeric as a new food ingredient in these drinks practicable globally.

2.5 Conclusion

Consumers' growing awareness of the relationship between health, well-being and dietary intake makes turmeric an increasingly popular food item for its acclaimed health-supporting properties. This study critically reviewed consumers' appreciation of turmeric in various food categories and dishes from different countries. This is, to the best of our knowledge, the first systematic review on turmeric in this area. Turmeric has unique sensory qualities that many consumers appreciate, as evidenced by the popularity of analogue ingredients like ginger. While turmeric can be pungent and bright yellow in colour, it can also develop a bitter taste and a dark yellow colour when used in larger concentrations. The golden yellow colour imparted to foods fortified with turmeric contributed most to their consumers' appreciation. However, excessive amounts of volatiles and phenolic compounds present in turmeric negatively affected the sensory evaluation of the taste.

This review identified that consumer appreciation for turmeric-fortified foods was strongly related to the food category. Turmeric was more preferred in snacks, pastry, beverages and soups because its pungency and bitter taste were more noticeable when combined with meat and dairy products. Overall, up to 0.3% w/w, 1% v/v, 5% w/w, 6% w/w, 10% v/v, and 20% w/v turmeric can be added to meat, dairy, snacks, pastry, beverages, and soups, respectively, without affecting the sensory acceptability. Therefore, we conclude that a rise in turmeric consumption as a food ingredient necessitates the selection of the appropriate dishes that are adapted to the tastes of local customers.

Fortification of popular beverages like *zobo* and soya milk with turmeric will lead to further developments in turmeric production, processing, distribution, and consumption, thereby increasing agricultural production and thus the incomes of small-scale food producers (especially youth, women and indigenous people), and contribute to a sustainable food and nutrition system. Training in the development of turmeric-fortified foods could also be incorporated into SDG implementation programs to assist in achieving Sustainable Development Goals, reduce poverty, enhance and improve rural livelihoods.

Conflicts of interest

There are no conflicts to declare.

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References

1. Guerrero L, Guàrdia MD, Xicola J, Verbeke W, Vanhonacker F, Zakowska-Biemans S, et al. Consumer-driven definition of traditional food products and innovation in traditional foods. A qualitative cross-cultural study. Appetite. 2009;52(2):345-54.

2. Buch SP, S.; Aparnathi, K. D. Evaluation of efficacy of turmeric as a preservative in paneer. Journal of Food Science and Technology. 2014;51(11):3226-34.
3. Kifelew H, Bekele D, Yadesa L, Getu A, Getachew W, Hailemichael G, et al. Result of Turmeric Variety Trial in Ethiopia. International Journal of Research Studies in Agricultural Sciences. 2018;4(9):34-8.
4. Milon M, Kabir M, Hossain M, Rahman M, Azad M, Hashem M. Value-added beef meatballs using turmeric (*Curcuma longa*) powder as a source of natural antioxidant. Sciences. 2016;3(4):52-61.
5. Lim HS, Park SH, Ghafoor K, Hwang SY, Park J. Quality and antioxidant properties of bread containing turmeric (*Curcuma longa* L.) cultivated in South Korea. Food Chemistry. 2011;124(4):1577-82.
6. Lim HS, Ghafoor K, Park SH, Hwang SY, Park J. Quality and antioxidant properties of yellow layer cake containing Korean turmeric (*Curcuma longa* L.) powder. Journal of Food & Nutrition Research. 2010;49(3).
7. Adegoke G, Oyekunle A, Afolabi M. Functional Biscuits from Wheat, Soya Bean and Turmeric (*Curcuma Longa):* Optimization of Ingredients Levels Using Response Surface Methodology. Research Journal of Food and Nutrition. 2017;1(1):13-22.
8. Arulkumar A, Ramanchandran K, Paramasivam S, Palanivel R, Miranda JM. Effects of turmeric (*Curcuma longa*) on shelf life extension and biogenic amine control of cuttlefish (*Sepia brevimana*) during chilled storage. CyTA-Journal of Food. 2017;15(3):441-7.
9. Muogbo C, Gbabo A, Nwakuba N. Field performance analysis of a tractor-drawn turmeric rhizome planter. Poljoprivredna tehnika. 2019;44(2):33-46.
10. Govindarajan V, Stahl WH. Turmeric-chemistry, technology, and quality. Critical Reviews in Food Science & Nutrition. 1980;12(3):199-301.
11. Mane R, Kshirsagar R, Sawate A, Patil B, Kale R. Studies on evaluation of physicochemical and nutritional properties of fresh turmeric rhizome. Journal of Pharmacognosy and Phytochemistry. 2018;7(2):2895-7.
12. Prasad S, Aggarwal BB. Turmeric, the golden spice. Herbal Medicine: Biomolecular and Clinical Aspects 2nd edition: CRC Press/Taylor & Francis; 2011.
13. Nwaekpe J, Anyaegbunam H, Okoye B, Asumugha G. Promotion of turmeric for the food/pharmaceutical industry in Nigeria. Journal of Experimental Agriculture International. 2015;8(6):335-41.
14. Olojede A, Iluebbey P, Dixon A. IITA/NRCRI Collaborative Germplasm and data collection on minor Root and Tuber Crops in Nigeria. Annual report. 2005:77-81.

15. Hardiman D. Indian medical indigeneity: from nationalist assertion to the global market. Social History. 2009;34(3):263-83.
16. Grant KL, Schneider CD. Turmeric. American Journal of Health-System Pharmacy. 2000;57(12):1121-2.
17. Veena VV, Gehlot S. Historical perspectives of nutrition science: Insights from Ayurveda. J Nat Rem. 2019;19(1):32-42.
18. Tabish SA. Complementary and alternative healthcare: is it evidence-based? International Journal of Health Sciences. 2008;2(1):V-IX
19. De Jager P. Turmeric: the Ayurvedic spice of life: Vidyasagar Publications in conjunction with Pioneer Imprints; 2010.
20. Gang DR, Ma X-Q. Ginger and turmeric ancient spices and modern medicines. Genomics of Tropical Crop Plants: Springer; 2008. p. 299-311.
21. Maheshwari RK, Chauhan A, Mohan L, Maheshwari M. Spice up for scrumptious tang, cologne & wellbeing. J Global Biosci. 2014;3:304-13.
22. Verma RK, Kumari P, Maurya RK, Kumar V, Verma R, Singh RK. Medicinal properties of turmeric (*Curcuma longa* L.): A review. IJCS. 2018;6(4):1354-7.
23. Lim S-T, Han J-A. Improvement in antioxidant functionality and shelf life of *yukwa* (fried rice snack) by turmeric (*Curcuma longa* L.) powder addition. Food chemistry. 2016;199:590-6.
24. Debjit Bhowmik C, Kumar KS, Chandira M, Jayakar B. Turmeric: a herbal and traditional medicine. Archives of Applied Science Research. 2009;1(2):86-108.
25. Gopinath H, Karthikeyan K. Turmeric: A condiment, cosmetic and cure. Indian Journal of Dermatology, Venereology, and Leprology. 2018;84(1):16.
26. Khajehdehi P. Turmeric: Reemerging of a neglected Asian traditional remedy. Journal of Nephropathology. 2012;1(1):17.
27. Park SH, Lim HS, Hwang S-Y. Evaluation of antioxidant, rheological, physical and sensorial properties of wheat flour dough and cake containing turmeric powder. Food Science and Technology International. 2012;18(5):435-43.
28. Rödiger M, Hamm U. How are organic food prices affecting consumer behaviour? A review. Food Quality and Preference. 2015;43:10-20.
29. Cunha LM, Cabral D, Moura AP, de Almeida MDV. Application of the Food Choice Questionnaire across cultures: Systematic review of cross-cultural and single country studies. Food Quality and Preference. 2018;64:21-36.

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30. Cox DN, Hendrie GA, Carty D. Sensitivity, hedonics and preferences for basic tastes and fat amongst adults and children of differing weight status: A comprehensive review. Food Quality and Preference. 2016;48:359-67.
31. Cerri J, Thøgersen J, Testa F. Social desirability and sustainable food research: A systematic literature review. Food Quality and Preference. 2019;71:136-40.
32. Gaur GK, Rani R, Dharaiya CN, Solanki K. Development of herbal milk using tulsi juice, ginger juice and turmeric powder. IJCS. 2019;7(2):1150-7.
33. Kishor K, David J. Sensory Evaluation of Value Added Cottage Cheese with Different Levels of Chick Pea Milk and Turmeric Powder. Advances in Life Sciences 2016;5(23):10909-11.
34. Foda MI, El-Aziz MA, Awad A. Chemical, rheological and sensory evaluation of yoghurt supplemented with turmeric. Int J Dairy Sci. 2007;2(3):252-9.
35. Singh RR, Singh R, Shakya B. Impact of turmeric addition on the properties of paneer, prepared from different types of milk. International Journal of Current Engineering and Technology. 2014;4(3):1874-83.
36. Maji S, Ray PR, Ghatak PK. Fortification of *Lassi* with Herbal Extracts-Effects on Quality and Total Phenolic Content. Int J Curr Microbiol App Sci. 2020;9(11):444-53.
37. Muhammad A, Rahman Z, Ayub M, Durrani Y, Ali S, Tabassum A, et al. Inhibitory Effect of Ginger and Turmeric on Rhizopus stolonifer Growth on Bread. Journal of Food Processing & Technology. 2014;5(5):1.
38. Fadairo O, Diósi G, Mironescu I, Máthé E. Development of fortified bakery products based on *kokoro*, a traditional Nigerian snack. *Acta Universitatis Sapientiae, Alimentaria*. 2018;11(1):145-60.
39. Maizura M, Aminah A, Aida WW. Antioxidant capacity and consumer acceptability of herbal egg tofu. LWT-Food Science and Technology. 2016;65:549-56.
40. Adegunwa M, Omolaja N, Adebowale A, Bakare H. Quality Evaluation of Snacks Produced from Blends of Unripe Plantain, Bambara Groundnut and Turmeric Flour. Journal of Food Processing and Preservation. 2017;41(1):e12760.
41. Mane R, Kshirsagar R, Sawate A, Kale R. Studies on formulation and sensory evaluation of turmeric-based orange RTS beverage. Journal of Pharmacognosy and Phytochemistry. 2018;7(2):2898-900.
42. Mane R, Pawar V, Kshirsagar R. Studies on development of process technology for formulation, sensory evaluation and storage studies of fresh turmeric rhizome juice-based orange RTS beverage. IJCS. 2019;7(1):1704-9.

43. Rozan MA. Carotenoids, Phenolics, Antioxidant Activity and Sensory Attributes of Carrot Jam: Effect of Turmeric Addition. Egypt Journal of Food Science. 2017;45:113 - 23.
44. Rozan MA, Bayomy HM, Boriy EG. Effects of turmeric addition on chemical composition, antioxidant activity and sensory evaluation of lentil soup. Alexandria Science Exchange Journal. 2018;39(January-March):1-6.
45. Pawar P, Kshirsagar R, Sawate A, Patil B. Standardization, preparation and quality evaluation of turmeric soup. Journal of Pharmacognosy and Phytochemistry. 2017;6(5):256-60.
46. Buch S, Pinto S, Aparnathi K. Evaluation of efficacy of turmeric as a preservative in paneer. Journal of Food Science and Technology. 2014;51(11):3226-34.
47. Maji S, Ray PR, Ghatak PK, Chakraborty C. Total phenolic content (TPC) and quality of herbal lassi fortified with Turmeric (*Curcuma longa*) extract. Asian Journal of Dairy and Food Research. 2018;37(4):273-7.
48. Hussain SA, Panjagari NR, Singh R, Patil G. Potential herbs and herbal nutraceuticals: food applications and their interactions with food components. Critical Reviews in Food Science and Nutrition. 2015;55(1):94-122.
49. Rahaie S, Gharibzahedi SMT, Razavi SH, Jafari SM. Recent developments on new formulations based on nutrient-dense ingredients for the production of healthy-functional bread: a review. Journal of Food Science and Technology. 2014;51(11):2896-906.
50. Olife IC, Onwualu AP, Uchegbu KI, Jolaoso MA. Status assessment of spice resources in Nigeria. Journal of Biology, Agriculture and Healthcare. 2013;3(9):12-8.
51. Osawaru M, Eholor R. Ethnotaxonomy and traditional use of turmeric (*Curcuma longa* L.) among some Nigerian tribes in South Edo State, Nigeria. Plant Archives. 2010;10(1):181-9.
52. Sopher DE. Indigenous uses of turmeric (Curcuma domestica) in Asia and Oceania. Anthropos. 1964(H. 1./2):93-127.
53. Sasikumar B. Turmeric. Handbook of herbs and spices: Elsevier; 2012. p. 526-46.

CHAPTER 3

Food neophobia among Nigerian consumers: A study on attitudes towards novel turmeric-fortified drinks

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Abstract

BACKGROUND: Knowledge on food neophobia among African consumers is scarce. Yet a good understanding in this area is essential to support the acceptance of new foods, for instance, when fortifying familiar foods to improve the health and nutritional status of the populace. In this paper, food neophobia among Nigerian consumers was assessed by their attitudes towards unfamiliar beverages, namely turmeric-fortified drinks. Turmeric was chosen as the Nigerian government is stimulating its production for income generation, but the spice is not commonly used in Nigerian foods and drinks.

RESULTS: Familiar street-vended drinks, i.e., soyamilk and the hibiscus-based drink *zobo*, were fortified with turmeric. Respondents (483) were allowed to try both the familiar and unfamiliar (turmeric-fortified) drinks. Subjects also filled in a 20-item questionnaire concerning attitudes toward food and eating. Food neophobia was measured by the Food Attitude Survey (FAS) instrument ratings. Using the FAS, people who reported liking the fortified drinks (‘likers’) were compared with those who disliked the drinks (‘dislikers’) and those who were unwilling to try the drinks (‘will not tryers’). Males were found to be more food neophobic than females. Middle-class income earners, the age group of 26–35 years and respondents with the highest education levels also showed a more food neophobic attitude towards turmeric-fortified drinks.

CONCLUSION: Practical insights are given regarding the introduction of novel foods to Nigerian consumers by paying attention to the attitudes of respondents with different demographic characteristics. The use of influencers seems to be a promising approach to addressing food neophobia in Nigeria.

Keywords: Food Attitude Survey; Food Neophobia Scale; *Curcuma longa*; consumer research; spice; *zobo*

3.1 Introduction

The potential of turmeric (*Curcuma longa* L.) to boost the income of small-scale Nigerian farmers encouraged the government to financially support research on turmeric farming in Nigeria through the National Roots Crops Research Institute in Umudike[1] and its research locations across the country. Together these are piloting tests of turmeric accessions for official distribution to local farmers.[2] Turmeric is a globally used condiment and colouring agent.[3] The crop is also one of the most broadly investigated as a natural remedy against various illnesses. In Asian traditional medicine, turmeric is used to treat infectious diseases, throat infections, gynaecological ailments, hepatic disorders and other chronic diseases.[4] In Nigeria, turmeric is boiled (with or without other herbs) and sipped to treat malaria, yellow fever, gastric ulcer, high blood pressure, cold, convulsions, and rheumatoid and emotional disorders.[5] As turmeric is widely available, is relatively cheap and has health benefits, it is increasingly being added to existing foods such as bread,[6] biscuits,[7] chocolate,[8] cakes[9,10] and beverages.[11]

Humans vary substantially in their attitudes towards novel foods, with some displaying a strong interest in trying them and others displaying great apathy. Linked to the knowledge of acceptance of novel foods is the approach of food neophobia, which is the unwillingness to consume or the avoidance of novel foods.[12] Consequently, food neophobia can influence the acceptance of novel foods. Therefore, knowing its prevalence among specific groups of consumers is of concern to food product designers and industries. Food neophobia is considered to be a common property of omnivorous animals, including humans, but studies of food neophobia in people have shown large individual differences. Pliner and Hobden[13] developed the initial psychometric tool intended to test individual differences in food neophobia, namely the Food Neophobia Scale (FNS). An alternative method for the measurement of food neophobia, known as the Food Attitudes Scale (FAS), was developed by Frank *et al*.[14] Results of the FNS and FAS envisage individual differences in likings for new *versus* accustomed foods.[15]

Nutritionally desirable new foods are difficult to introduce in specific nations because of neophobia and variability in the diet. This has led to multicultural research in five nations in Europe and in the USA.[16] Moreover, food neophobia studies among young adults in Australia were initiated by uncertainties about food familiarity among various cultures and the impact of socio-economic status (SES).[17] MacNicol *et al*.[18] conducted related studies on the connection between behaviour, personal attitude and eating performance among Scottish adolescents. Choe *et al*.,[19] made the first attempt to validate the Food Neophobia Scale in Asia. They studied the trend of food neophobia amid the Korean population. Another recent study in Asia[20] was done to reveal the situation of food neophobia among three population groups comprising Malay, Indian and Chinese studying in the higher institutions in Malaysia.

The influence of socio-economic features on the attitude of consumers in Brazil about innovative food technologies was studied to compare the familiarity and willingness to try new foods developed by conventional and non-conventional technologies.[21] It was recommended that consumers should be updated about the benefits of any new food derived from traditional food to successfully enter the market and reach a competitive stage. Similarly, the findings of Martins and Pliner, [22] on the basic reasons for acceptance or rejection of new and familiar food, suggested that one approach for limiting a food neophobic reaction to new foods was to actively highlight the positive characteristics of the products to reduce the individual perception of the negative features of these foods. In general, exposure to unfamiliar foods decreases neophobic responses and this exposure in turn influences willingness to try new foods.[19,23–26]

Yet, we know of no study on food neophobia in Africa. Such data would benefit researchers working to improve the nutritional status of the populace by developing novel foods for inclusion in the diet. Nigerian industries have been voluntarily fortifying staple foods since the 1990s. Mandatory fortification of wheat and maize flour, edible vegetable oil and sugar was enacted in February 2000 and enforcement began in September 2002.[27] Fortified foods turned out to be novel, though, and foods to be fortified must be consumed adequately by a large proportion of the target individuals in a population.[28] Sensory attributes that are most affected when fortifying food with turmeric are appearance (colour) and taste. These attributes may therefore impact the overall acceptability of such turmeric-fortified foods.

Since food neophobia can influence preferences towards novel foods, understanding its potential impact on consumers' food acceptance is an important issue for food researchers, product developers and marketers. Hence this study was carried out to assess the attitude of Nigerian consumers towards novel drinks and to gain insight into the prevailing level of food neophobia. For this purpose, turmeric-fortified drinks from two street-vended beverages, namely *zobo* and soya milk, were developed. The addition of turmeric to *zobo* and soya milk is novel in Nigeria. This root, indigenous to India, is currently gaining attention in the farming systems and research in Nigeria because of its bioactive properties and health benefits.

Nwaekpe *et al*.[1] reported how farmers can tap into the potential of prevailing favourable soil and climatic conditions to increase turmeric production in Nigeria. Akpan *et al*.[29] also reported that turmeric incorporation into the farming scheme of Nigeria is mostly important for revenue and nutrition improvement. However, in a study conducted by Osawaru and Eholor,[30] the respondents (who belonged to nine different tribes in Nigeria) used turmeric only as spice and medicine. The fact that Nigerian food processors are not yet tapping into the potential of using turmeric for income generation and improving nutrition could be because the options for its inclusion in food products and their acceptance have not been properly studied.

Zobo is a refreshing, non-alcoholic street-vended beverage in Nigeria, produced by boiling water with the calyces of the roselle flower (*Hibiscus sabdariffa*) to obtain a dark-red coloured and sour-tasting beverage after filtration. Depending on the street-vended food processor and geopolitical location, sugar, and spices such as garlic and ginger or fruits, may be added according to taste.[31,32] The drink is a good source of vitamins and minerals.[33,34] Soya milk has good nutritional and health features. In many nations, soya milk is a vegetarian alternative for milk and for lactose intolerance.[35–38] Like *zobo*, soymilk is a common drink for Nigerians of all ages. Street food vendors – mainly local women – produce and sell both drinks on the street as a low-cost beverage to generate income and alleviate poverty.[31,36]

Zobo and soya milk are consumed across diverse socio-economic classes and cultural groups in Nigeria.[39–41] Presently *zobo* is consumed by several million people in West African countries, particularly among the youth, who perceive *zobo* as a relatively cheap and soothing non-alcoholic drink in societal meetings.[41,42] Hence the second aim of this study was to assess the relationship between food neophobia levels and demographic factors such as age, gender, education, income and exposure to other cultures within Nigeria. This aim was designed to test the hypothesis that food neophobia scores would decrease with increasing education and exposure to other cultures but would increase with increasing income and age.

3.2 Material and methods

Study design

Soya milk was prepared as described by Obadina *et al*.[35] The soya milk without turmeric was presented to respondents as SY (soya milk control). To produce turmeric-fortified soya milk, turmeric paste was added to soya milk. Chopped turmeric (40 g in 80 mL water) was blended in a Waring blender (blender 8011ES, model HGB2WTS3, Waring, TX, USA) until a fine paste was obtained. This paste was added as 5%, 7.5% and 10% w/v to the soya milk, boiled and allowed to cool. The choice of these concentrations was based on the usual intake of boiled turmeric milk to treat sore throat infections in India. The resulting drinks were presented to the respondents as STA, STB and STC, respectively. *Zobo* drink was prepared according to the method of Adesokan *et al*.[34] The drink without turmeric was presented to respondents as ZB (*zobo* control). Turmeric paste was added to *zobo* to produce turmeric-fortified *zobo*. Turmeric paste (as described above) was added as 2%, 6% or 10% w/v of zobo and presented as ZTA, ZTB and ZTC, respectively. The addition of turmeric to *zobo* is new. We hypothesized that the nutritional quality of *zobo* with 6% and 10% turmeric might be lower than for 2% turmeric due to aggregation or precipitation at higher concentrations.

Measurement of food neophobia

A review of tools to test food neophobia and willingness to try unfamiliar foods suggested 13 instruments from 255 studies.[43] Out of these 13 instruments, the Food Attitude Scale (FAS) described by Frank *et al*.,[14] to measure individual attitudes to food and willingness to try novel foods was used in this study.

Questionnaire

The questionnaire was written in English and comprised four sections. The first section contained questions on respondents' willingness to try turmeric-fortified drinks in stimulating and non-stimulating circumstances with questions on consumption of indigenous drinks, namely *zobo* (ZB) and soya milk (SY), and the respondents' feelings/reactions if they were presented with turmeric-fortified *zobo* and soya milk. Questions on two fictitious drinks – namely '*zokurma*' and '*sokurma*'– were also included to test the reaction of our respondents while trying an unknown drink based merely on its name.[44] Respondents answered yes or no to the first two questions asking if they drank soya milk and/or *zobo*, while the questions on willingness to try drinks in stimulating and non-stimulating circumstances were answered on a 5-point Likert scale,[45] with options ranging from 'very interested' to 'very disinterested'. Thereafter, respondents were presented with eight drinks, namely SY, STA, STB, STC, ZB, ZTA, ZTB and ZTC (codes as described in the 'Study design' section, above). The respondents were asked to taste and rate the drinks on a 9-point scale, labelled as follows: 1, Dislike extremely; 2, Dislike very much; 3, Dislike moderately; 4, Dislike slightly; 5, Neither like nor dislike; 6, Like slightly; 7, Like moderately; 8, Like very much; 9, Like extremely.[46,47] In the second part of the survey, the respondents were requested to judge all the drinks on a 5-point scale ranging from 'like' to 'will not try'.[14] The detailed meaning of this 5-point 'like' to 'will not try' scale, as described by Frank and van der Klaauw,[14] were also made known to the respondents as follows:

Like = I really like this drink. I think it tastes good.
Neutral = I can take or leave this drink. It tastes OK.
Dislike = I dislike this drink. It tastes awful.
Will try = I've never tried this food, but would taste it if I had the opportunity.
Won't try = I've never tried this food, and never intend to try it.

The third section of the survey concerned general data such as gender, age, level of education attained, the number of geopolitical zones visited and household income.[19] Geopolitical zones and household income were aligned with the data of the National Bureau of Statistics Office in Nigeria.[48] For ease of resource sharing, the 36 states in Nigeria are politically classified into six geopolitical zones, namely North-East (NE), North-Central (NC), North-West (NW), South-East (SE), South-West (SW), and South-South Zone. Consumption patterns, recipes and methods of preparation of similar foods vary across these geopolitical zones.[49,50] Geographical differences across Nigeria led to Uwaifo and Uddin[51] proposing that the educational curricula should also vary from zone to zone. In Nigeria, the present system of education, whose curriculum is expected to meet the Millennium Development Goals (MDGs), is called the Universal Basic Education (UBE), otherwise known as the 9-3-4. This system was introduced in 1999 and had been expected to take off since 2006 to replace the 6-3-3-4 system of education. Household income was categorized into low, middle and high income, signifying a respondent's financial strength. The last part of the questionnaire contained a list of 20 statements concerning attitudes towards food and eating.[44] Each statement was scored on a 5-point category scale that ranged from 'strongly agree' through 'neutral' to 'strongly disagree'.[14] Responses to these statements were statistically compared for the groups of selected 'likers' and 'dislikers', the 'will not tryers' and the overall average.

Respondents

This study was conducted in Akure, the capital town of Ondo State, in the South-West geopolitical zone of Nigeria. The respondents were 16–75 years old. Several challenges facing technology and educators in the implementation of 9-3-4 in primary schools[52] made both the young and old respondents in our study the beneficiaries of the 6-3-3-4 system of education. Graduate students of the Federal University of Technology, Akure, were trained to administer the questionnaires to the participants. The respondents were not specially recruited as *zobo,* and soya milk are hawked in the streets in Nigeria and consumed across all ages. The graduate students visited respondents in their various stores, houses, offices, along the streets, etc. with the questionnaire and the turmeric-fortified drink samples. The data were collected within 3 weeks in the fall/winter of 2018. It took 30–45 min for each respondent to complete the sensory test and accompanying FAS questionnaire.

Data analysis

About 500 questionnaires were distributed, and 483 were returned for analysis. The FAS was analysed by using the XLSTAT version 2018.7 auto sum command to sum the number of responses in the five answer categories (i.e., from 'like' to 'will not try'), which reflected the general reactions to the turmeric- fortified drinks used in the survey. For the categories of 'likers' and 'dislikers', 60 respondents each were randomly selected for comparison of their responses to the 20-item statements on food-related attitude, in line with data analysis according to the FAS.[14] Randomization was conducted using the command 'RAND ()' in a Microsoft Excel 2016 spreadsheet. All the 'will not tryers' were included because they were few in number. Furthermore, a group of 'average' subjects (n = 60) was selected for comparative analysis. Subjects selected for this group met the criterion of having less than 0.5 standard deviations from the sample mean in their number of 'like', 'neutral', 'dislike', 'will try' and 'will not try' responses.[14] Lastly, respondents who did not give a response (i.e. score zero) to one of the 20 questions were deleted from the group, leaving us with n = 44, 47, 43 and 13 fully completed questionnaires for average, 'likers', 'dislikers' and 'will not tryers', respectively. The reliability of the selected group was tested based on the percentage difference between the original mean and the randomized mean, i.e., original mean/randomized mean multiplied by 100, which gave 98% in this study. SPSS version 23.0 was used for the descriptive statistics of consumer awareness and willingness to try turmeric-fortified drinks in stimulating and non-stimulating conditions, as well as analysis of variance (ANOVA) to determine the differences in sensory attributes among the turmeric concentrations for the 402 respondents who consumed both turmeric-fortified *zobo* and soya milk,[46] and for the five measures ('like' to 'will not try') across the respondents' demographic information. Excel 365 was used for binomial analysis to also test whether there were differences in consumption of soya milk and *zobo* by all the respondents.

3.3 Results

Respondents' profile

We distributed 500 questionnaires, and 483 were returned for analysis (96.6%). The study was conducted in the South-West (SW) geopolitical zone, which is the predominant Yoruba ethnic region, yet 5.4% (N = 26) were Igbos (SE and SS), Hausas (NE, NC and NW) 3.1% (N = 15) and the rest of the respondents (91.5%) were Yorubas (N = 442). 35% (N = 169) of the respondents had not visited any geopolitical zone aside from their own, while 20.1% (N = 97), 16.8% (N = 81) and 28.2% (N = 136) had visited one, two and three or more geopolitical zones, respectively. Among 483 respondents, (55.9%, N = 270) were male, and 44.1% (N = 213) were female. N = 217 (44.9%) of the respondents had a university education. N = 170 (35.2%) of them were high school certificate holders, while 19.9% (N = 96) of the respondents were basic school certificate holders. 25.1% (N = 121) of the respondents belonged to the low-income group, 34.2% (N = 165) of the respondents belonged to the middle-income group, while 40.8% (N = 197) of the respondents belonged to the high-income group.

Nigerian consumer attitudes towards turmeric-fortified drinks

Figure 3.1 presents the respondents' general attitudes to turmeric-fortified drinks used in this survey. Likers' scores decreased as the concentration of turmeric increased for all the samples used. The rate of dislike also increased as the turmeric concentration increased. However, the respondents were more neutral than liking the drinks with the lowest turmeric concentrations (5% turmeric soya milk and 2% *zobo*) in the drink.

Food neophobia attitude of respondents in relation to demographic factors

In Nigeria, states with similar cultures, ethnic groups and common history are categorized into the same geopolitical zone. Aside from variation in the geopolitical zone, significant urban-rural differences also exist in the achievement of pupils at the elementary (primary) educational level in Nigeria. [53] The recipient of the 6-3-3-4 type of educational system would spend 6 years in elementary school, 3 years in junior secondary school, 3 years in senior secondary school and 4 years in the tertiary institutions such as colleges of education, polytechnics, and universities. The 6-3-3-4 system of education in Nigeria is labour related. It is to provide the child with simple tools to prepare him or her for local crafts at the elementary stage.

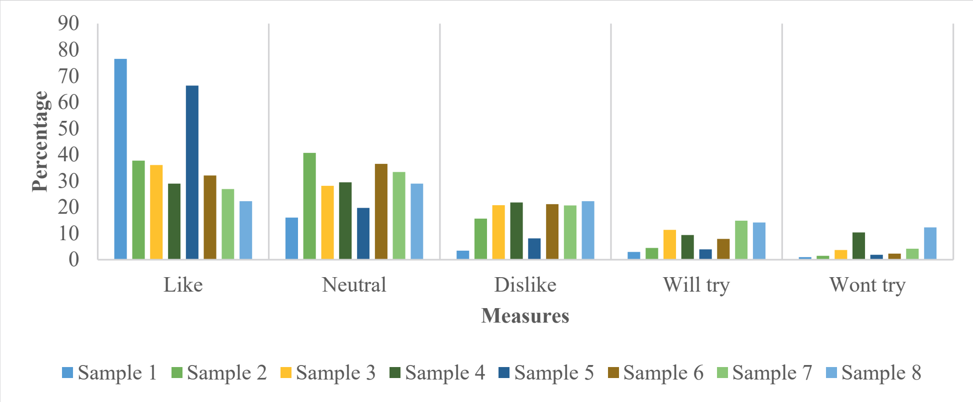

Figure 3.1: Responses of 483 Nigerian consumers to two familiars (samples 1 and 5) and six unfamiliar beverages (samples 2-4 and 6-8) according to the five-point scale of the Food Attitude Scale (FAS) developed by Frank *et al.*[14] **Keys:** Samples 1, 2, 3, 4, 5, 6, 7 and 8 represent SY, STA, STB, STC, ZB, ZTA, ZTB and ZTC, respectively.

Achievement of vocational skills is the focus at the secondary stage, while the tertiary stage is professionally oriented. In brief, 6-3-3-4 is a purposeful education, that aids its beneficiaries to function morally, intelligently, economically, politically and socially.[51]

Table 3.1 presents the results on the relation between food neophobia and two characteristics of our respondents, namely their level of education and the number of geopolitical zones they visited. This in-depth analysis was performed because the attitude of the highly educated group of respondents was classified as clearly neophobic, with scores of 21% ‘dislike’ and 5% ‘will not try’, as shown in Fig. 3.2(B). A significant difference ($p < 0.05$) was established between the respondents with elementary education and those with university education. This indicates that only 6 years of primary education limits the social attitude and interaction of its recipients. Nigerians with this level of education are moderately functional economically and politically than socially and intellectually. Moreover, significant differences ($p < 0.05$) were found for people who had visited two, three or more geopolitical zones in Nigeria and those who had not travelled outside their geopolitical zone.

Table 3.1: Education level[n] and geopolitical zone[n] visited outside the geopolitical zone/area of the respondents

	N	Mean	Std. Deviation
Education level			
Elementary	33	1.61*	0.75
Secondary	134	1.96	0.92
University	196	2.23*	1.16
Geopolitical zones visited			
0	79	1.68*	0.91
1	87	1.83*	0.78
2	75	2.12*	0.99
3 or more	107	2.22*	1.06

*The mean difference is significant at the 0.05 level. [n]Total N values of 363 and 348 respondents that indicated educational level and geopolitical zone(s) visited respectively.

Another significant difference ($p < 0.05$) existed between people who had visited one zone outside their own and those who had been to three or more places, i.e. had had more contact with people from other areas with different living styles, cultures and probably slight taste differences in familiar foods due to variations in preparation and recipe. This result indicated that the cultural diversity of Nigeria has implications for the attitude of the populace towards novel food. The attitudes of the 483 respondents as related to the other demographic characteristics in our study, i.e. gender, age and income, are also shown in Fig. 3.2(A, C, D) respectively.

3

Respondents' willingness to try and overall acceptability of turmeric-fortified drinks

Of our respondents, 83.2% ($N = 402$) consume soya milk whereas 16.8% ($N = 81$) do not; and 90.5% ($N = 437$) consume *zobo* whereas 9.5% ($N = 46$) do not. This result indicates that both soya milk and *zobo* are familiar drinks in Nigeria. However, the difference in their consumption rate was significant at t (964) = 1.96, $P = 0.00$ (one-tailed). Table 3.2 shows the willingness to try novel foods in general, as well as in stimulating and non-stimulating circumstances. The most positive answer was for 'If your favourite actor/actress or clergyman offers you *sokurma*, how will you feel about trying it?' ($M = 2.27$, SD = 0.96), and the lowest score for 'If refreshment at your friend's house is *zobo* with turmeric flavour, how will you feel about drinking that type of drink?' ($M = 1.89$, SD = 0.79). This result indicated that the respondents were more willing to take unknown drinks irrespective of the name given to the drink (like *sokurma*, which is a fictitious name and the drink was not included in the study) if their favourite actor/actress or clergyman offered it to them rather than their families and friends. The result is also an indication that public figures could be a social influencer for the acceptability of unfamiliar drinks in Nigeria.

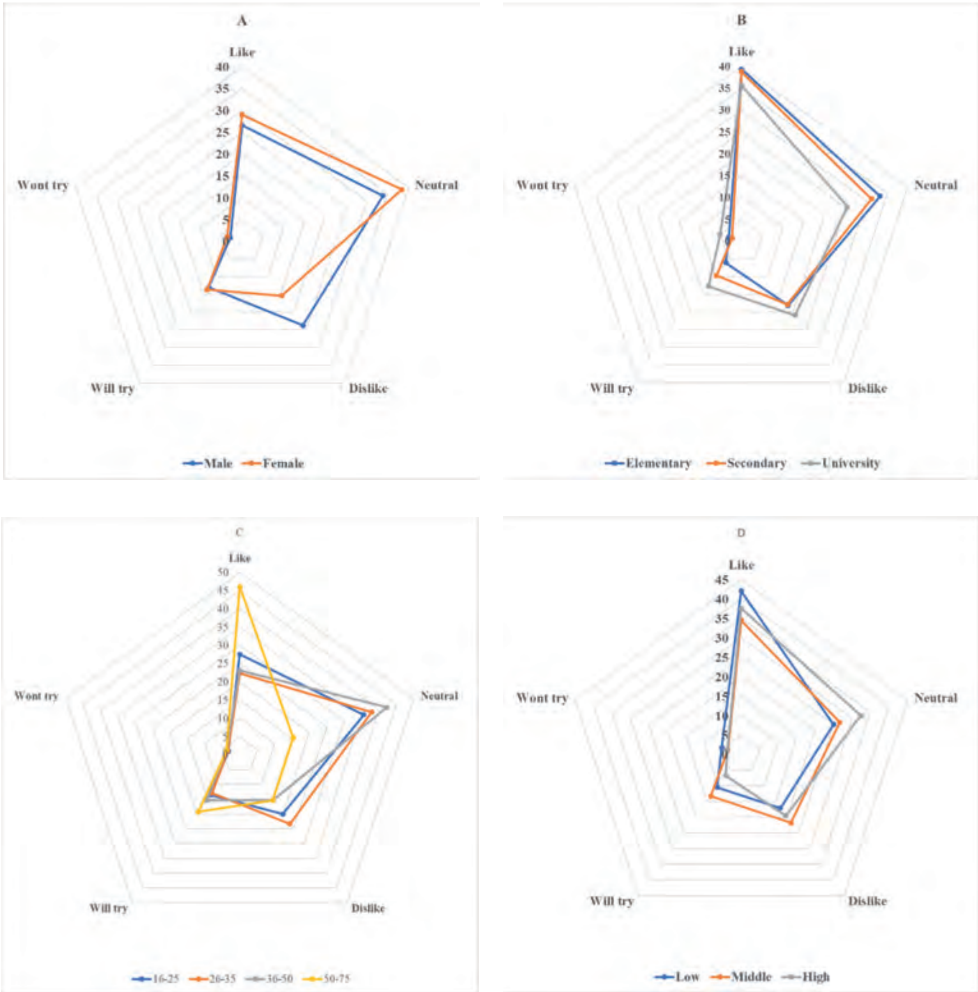

Figure 3.2: Respondents' demographic factors *vs*. their responses (%) to the question of whether or not they would try turmeric-fortified drinks. A=gender, B=level of education, C=age and D=class of income.

Table 3.2: Respondents' willingness to try turmeric-fortified drinks in stimulating and non-stimulating circumstances

Item		Mean	SD
1	Assuming you attended a friend's feast, and you were served *zokurma** how will you feel about drinking it?	2.22	0.97
2	If your favourite actor/ actress or clergyman offers you *sokurma***, how will you feel about trying it?	2.27	0.96
3	If a refreshment at your friend's house is *zobo* with turmeric flavour, how will you feel about drinking that type of drink?	1.89	0.79
4	If a refreshment at your favourite uncle's house is soya milk with turmeric flavour, how will you feel about trying that type of drink?	1.96	0.98
5	If your family member brought soya milk with a colour you have never seen before, how will you feel about trying it?	2.19	1.02

All questions were scored on a 5-point Likert scale; very interested, interested, indifferent, disinterested, and very disinterested.
*&** are the fictitious names given to turmeric-fortified *zobo* and soya milk, respectively.

Table 3.3 shows the scores of the sensory attributes for turmeric- fortified street-vended *zobo* and soya milk. The control street-vended drinks were liked much more than the unfamiliar turmeric-fortified street-vended drinks. However, turmeric-fortified drinks were liked slightly to moderately for appearance, mouthfeel, and overall acceptability for all the turmeric concentrations of *zobo* and soya milk by the 402 respondents who consumed both drinks in this study.

Responses to the 20-item FAS questions by average and extreme groups

The outcome of the selected respondents to the 20-item FAS questions is presented in Table 3.4. Responses of the 'average' and 'will not tryers' groups differ for some general FAS questions. The responses of the 'dislikers' were similar to those of the 'will not tryers' group, as were the responses of the 'likers' and the 'average'. Table 3.5 also shows the results of additional checks on respondents with the highest level of education for some selected questions from the general FAS questions. This group of respondents agreed that even though they love to drink they will not try to drink if they do not know what it is.

Table 3.3: Sensory scores* of turmeric-fortified *zobo* and soya milk

Samples	Appearance	Aroma	Taste	Mouthfeel	Overall acceptability
Zobo					
Zobo control	7.89±1.34[a]	7.78±1.40[a]	7.87±1.62[a]	8.01±1.32[a]	7.80±1.48[a]
2% turmeric	7.12±1.40[b]	7.00±1.49[b]	7.09±1.77[b]	7.31±1.33[b]	7.05±1.56[b]
6% turmeric	6.45±1.78[c]	6.68±1.80[c]	6.61±2.11[c]	6.87±1.81[c]	6.47±1.94[c]
10% turmeric	6.41±2.14[c]	5.89±2.13[d]	5.78±2.36[d]	6.16±2.12[d]	6.32±2.22[c]
Soya milk					
Soya milk control	8.14±1.04[a]	8.04±1.06[a]	7.99±1.39[a]	8.06±1.14[a]	8.10±1.07[a]
5% turmeric	7.30±1.30[b]	7.38±1.35[b]	7.02±1.72[b]	7.38±1.35[b]	7.39±1.27[b]
7.5% turmeric	6.84±1.66[c]	6.85±1.67[c]	7.14±1.84[b]	6.83±1.80[c]	7.00±1.63[c]
10% turmeric	6.34±2.02[d]	6.61±1.90[c]	6.53±2.14[c]	6.49±2.16[d]	6.72±2.34[c]

Keys: Means in the same column with a different superscript are significantly different at $p < 0.05$ for each sample. * Values are means of scores of 402 Nigerian respondents.

3.4 Discussion

Food neophobia studies across the globe

Research on food neophobia is common among Europeans.[54] Study aims, outcomes and relation between food neophobia and socio-economic factors, gender, age education and urbanisation in Asia, Australia, Europe, and South America as examined by the various researcher are reported in Table 3.6.

Food neophobia among Nigerian consumers

Food neophobia among Nigerian consumers was measured using the validated instrument developed by Frank *et al*.[14] to measure individual attitudes to food and willingness to try novel foods. As the inclusion of turmeric in street-vended food is novel in Nigeria, the main and most appropriate tool for this study is FAS to test consumer attitudes and preferences for turmeric-fortified drinks. This method was chosen because of its excellent internal and test-retest reliability[15] and its ability to provide useful suggestions regarding individual differences in food liking and attitudes.[44] The logic of the rating is the classification of both 'dislikers' and 'will not tryers' as food neophobic. Familiar street-vended drinks, i.e., soya milk and the hibiscus-based drink *zobo*, were fortified with turmeric.

Table 3.4: Mean responses[n] of likers, dislikers, won't tryers and average groups to the general FAS questions.

Statement	Likers (n= 47)	Dislikers (n=43)	Won't tryers (n=13)	Average (n=44)
i. I enjoy trying new drinks	2.5	2.4	1.8	2.8
ii. I like different ethnic drinks	3.3*	3.2*	1.9*	3.1*
iii. I find many drinks distasteful	3.0*	3.6	2.8	3.6*
iv. I only drink because I have to drink	3.2	3.4	3.7	3.4
v. I like to try new restaurants	2.7	3.2*	2.1*	3.3*
vi. Most of the time I can take or leave a drink	3.1	3.2	2.7	3.0
vii. I enjoy trying unusual drinks	3.7*	3.0*	3.2	3.4
viii. Having to drink is a bother	3.0	3.4	3.0	3.3
ix. I like to stick to the drinks I know	2.7	2.2*	2.7	3.0*
x. I like sugary drinks	2.7	2.4	2.5	2.7
xi. I find that many drinks I like are sweet	3.2*	2.4*	2.7	2.4*
xii. I'm not likely to try new drinks in a bar/restaurant	2.8	2.6*	3.2	3.3*
xiii. I love to drink	3.0	2.9	3.2	2.8
xiv. I won't try drinks if I don't know what it is	2.5	2.2	1.7	2.5
xv. A bad experience would keep me from trying a drink again	2.5	3.3	2.5	2.5
xvi. I think that many drinks are disgusting	3.4*	3.7*	3.0	3.4*
xvii. As a child, I was encouraged to try new drinks	2.7	3.0	3.2	3.2
xviii. I'll try a new drink even though one of its ingredients is something I don't like	3.2	3.4	3.1	3.5
xix. I have been called a selective drinker	2.8	3.2	2.5	3.0
xx. I consider myself a selective drinker	2.5	2.6	2.3	2.7

*The mean difference is significant at the 0.05 level. All questions were scored on a five-point category scale that ranged from strongly agree through neutral to strongly disagree. [n] Values are means of responses of 147 Nigerian respondents.

Turmeric was chosen because the Nigerian government is stimulating its production for income generation, but the spice is not commonly used in Nigerian foods and drinks. This research aimed to measure the attitude of Nigerian consumers towards novel foods. To date, information in this area is lacking in West Africa. We found consumer groups that were reluctant to try novel foods, i.e., exhibiting a degree of food neophobia. Initially, it was difficult to pinpoint the exact population group that exhibited food neophobia because we wanted to limit our classification to the group with the highest scores of both 'dislike' and 'will not try' as described by Frank *et al*.[14] The highest scores for 'dislikers' were found for males, respondents aged 26–35 years and people with a middle-class income.

Table 3.5: Responses of 158 respondents with the highest level of education to some questions from 20-item questions.

Questions	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree(%)
I enjoy new drinks	24.1	41.1	8.9	16.5	9.5
I love to drink	17.1	38.0	21.5	13.3	9.5
As a child, I was encouraged to try new drinks	15.2	30.4	23.4	17.7	13.3
Having to drink is a bother	12.7	27.8	29.1	18.4	12.0
I won't try a drink if I don't know what it is	32.3	43.7	8.9	11.4	3.8
A bad experience would keep me from trying a drink again	32.9	19.6	16.5	19.6	11.4
I consider myself a selective drinker	20.9	38.0	25.9	8.9	6.3

However, the group of respondents that really stood out consisted of those with a university degree. This group of respondents with the highest level of education showed distinct food neophobia in the food attitude survey (i.e., the highest percentages for both 'dislike' and 'will not try' of 21% and 5%, respectively).

Each geopolitical zone in Nigeria has a unique culture. Hence travelling from the south to the north of Nigeria exposes people to different cultures. Consumption patterns, recipes and methods of preparation of similar foods also vary across these geopolitical zones.[49,50] For these reasons, and as reported in previous studies,[19,25] education and travelling may decrease or even extinguish food neophobia. Therefore, we did not expect the group with the highest level of education to be neophobic. Subsequently, we checked whether there was a significant relation with respect to education and geopolitical zones visited by our respondents, but we found none. The area of residence could be a significant factor that led to the food neophobic attitude of the highly educated respondents in our studies. University students living in Akure can be categorized as students living in a semi-urban part of Nigeria when compared Akure residents to residents of large cities like Lagos and Ibadan in South-West Nigeria. The food neophobic attitude of this group with the highest level of education in relation to living areas supported the findings that students living in semi-urban areas were more neophobic than those living in an urban environment.[20]

Table 3.6: Reports of food neophobia studies in various countries

Food neophobia study by country and author(s)	Study characteristics	Outcomes
France, Germany, Britain, Italy, Switzerland and the United States of America [16]	Telephone interviews with adults from Europe and the USA to study their attitude to variety in food intake and choice.	The Americans, and the British to a certain level, centered on providing individual choices that were based on specific traits of food products. However, people from France, Germany, Britain, Italy and Switzerland stayed committed to collective eating traditions.
Australia[17]	Questionnaire answers of Australian high school students from rural and urban locations to the food neophobia scale, familiarity with certain foods and willingness to try those foods.	More significant contact with cultural diversity and higher socio-economic status has some effect on responses to unfamiliar foods. Urban respondents were more willing to try unfamiliar foods.
Scotland[18]	Dietary knowledge, behaviours, attitudes, and personality were surveyed in a group of 451 Scottish students.	The lower socio-economic level was linked to an increasing trend to have a picky attitude to food and a higher level of food neophobia.
Korea[19]	Description of Korean consumer responses to several non-ethnic foods.	Food neophobia among the Koreans was found to be higher than in Western nations. Even though the authors could not find significant differences in the level of food neophobia regarding Korean domestic proceeds, the study indicated that individuals who spent additional money appeared to be more neophilic than individuals who spent less money. Moreover, individuals who were exposed to new and exotic foods are less neophobic.
Malaysia, India and China[20]	Examining the connection between food neophobia and demographic characteristics (gender, age, marital status, education, race, living area and monthly income).	The study indicated that demographic factors are significantly related to the degree of neophobia. Malay scholars were more neophobic than Chinese and Indian scholars. Respondents living in semi-urban areas were more neophobic compared to those living in an urban environment. The authors concluded that the demographics and upbringing of an individual influence the neophobia level. Demographic factors with no exception of age and income significantly relate to food neophobia level.

Table 3.6: (continued)

Food neophobia study by country and author(s)	Study characteristics	Outcomes
Brazil[21]	Studies on the influence of socio-economic features on the attitude of consumers in Brazil about innovative food technologies to compare the familiarity and willingness to try new foods developed by conventional and non-convectional technologies.	A direct connection between familiarity with technologies and food neophobia was expected, but this was not confirmed. Instead, food neophobia was found to be influenced by socio-economic factors. The authors concluded that neophobia might be associated with an absence of information on new technologies.
Finland[25]	A representative sample of the Finns (n=1083) rated the familiarity of 20 foods designated to be ``familiar" or ``unfamiliar" and willingness to try them. Respondents also administered a 10-item questionnaire measuring their food neophobia.	Men were more neophobic than women, and the elderly (66±80 years) were more neophobic than the other age groups. Food neophobia scores decreased with increasing education and with the degree of urbanization.
Lebanon and the USA[55]	Assessment of food neophobia levels between American and Lebanese students (n= 1122). Determination of the effect of individual variables such as country of residence, socio-economic status (SES) on food neophobia levels. Examination of the effect of food neophobia levels on the familiarity and willingness to try ratings of familiar and novel foods.	Differences in FNS scores were found between American (29.8) and Lebanese (36.4) students ($P < 0.05$). Amount of countries visited, rate of eating ethnic foods and record of sickness after eating anew food were significant ($P < 0.05$)

The attitude of the 26- to 35-year-old age group showed food neophobicity with a dislike of 23%. Hence the striking outcome of a score of 46% 'like' for 50- to 75-year-old Nigerian respondents for turmeric-fortified drinks could have been caused by the fact that people of this age group have more traditional knowledge about the health benefits of turmeric. These health benefits were corroborated by studies on the neuropharmacological profile and chemical analysis of the essential oils of fresh rhizomes of turmeric cultivated in South-West Nigeria, which described that turmeric if boiled and sipped with or without other ingredients, can act as herbal medicine to heal various diseases.[5,30] Nigerians generally believe that herbal medicine, which is commonly known in South-West Nigeria as '*agbo*', is bitter and disgusting by nature. Therefore children, youth and learned people sometimes avoid it. The rejection of '*agbo*' by learned people is also due to fear of microbial contamination during preparation as a result of poor sanitary conditions at the local producers.

The results of demographic variables other than education and age showed that the attitude of middle-class income earners in this study tends towards food neophobia. In Nigeria, 92% of people in the middle-income class have a post-secondary education.[55] Apart from the educational factor, the attitude of Nigerian middle-income earners towards food neophobia is supported by the finding that SES influences the opportunity for exposure. A lower SES can be linked to an increased tendency for a picky attitude to food and food neophobia.[17,18] The results indicated that male respondents were more food neophobic (23.7% 'dislike') than female respondents, which agrees with Tuorila *et al*.[25]

Addressing food neophobia in Nigeria

Our study showed that food neophobia among Nigerians is most apparent among people who are characterized by two demographic factors, namely gender (male) and education (high). National Bureau of Statistics[48] data show that the youth literacy (15–24 years) rate in Nigeria is 76.1%, with males being more literate than females. The adult literacy rate, i.e., for 15 years and above, was 65.7% for males and 23.3% for females. Thus, in general, the literacy rate is high among men in Nigeria. We studied the highly educated group further with the 20-item statements. It was apparent that respondents with a university degree had in common that they agreed to enjoy trying new drinks (65.2%) and love to drink (55.1%) because they were encouraged as a child to try new drinks (45.6). Finally, 58.9% of this group considered themselves to be selective drinkers, which is in line with the statement of Frank *et al*.[14] that 'it is not accurate to characterize "won't tryers" and "dislikers" as uninterested in drinking or food generally'.

To address food neophobia, Choe *et al.* [19] suggested introducing new ingredients into familiar foods as this may be easier than introducing completely unfamiliar foods. Similarly, food neophobia can be addressed by introducing new ingredients to street-vended food in Nigeria. Our respondents were not specially recruited, as *zobo* and soya milk are hawked in the streets in Nigeria. The respondents were visited (like the street vendors) in their various stores, houses, offices, along the streets, etc. with the questionnaire and the turmeric-fortified drink samples. The overall acceptability of all concentrations of turmeric-fortified *zobo* and soya milk (6.32–7.05 and 6.72–7.39, respectively) indicate that healthy food can be promoted in Nigeria by fortification of familiar street-vended foods because of the existing familiar relationship between street vendors and consumers in terms of consumers' ease of accessibility to street-vended foods.

Another study on food neophobia[56] recommended addressing food neophobia with extra sales promotions, such as giving out free samples and free coupons. Free sampling points for new foods may be located within the university campus for easy access to obtain free samples by the students. Popular Nigerian musicians, comedians, actors and actresses are nowadays used for advertising food and herbal medicinal products across the country.[57,58] In our study, respondents were asked to imagine, while rating the samples, that they were in a social gathering and a popular actor/actress offered them a new drink. A public figure could also be used to distribute the free samples and introduce new foods to Nigerians, as the most positive answer was for 'If your favourite actor/actress or clergyman offers you *sokurma*, how will you feel about trying it?' (M = 2.27, SD = 0.96) when respondents' willingness to try turmeric-fortified drinks in stimulating and non-stimulating circumstances was tested.

The introduction of foods with added turmeric in Nigeria might also be facilitated by addressing the perception[59,60] among the Nigerian youth that perceives turmeric as an '*agbo*' herb, which they consider to be disgusting. Health consciousness can also be a positive influencer[61] for acceptance of turmeric-fortified drinks in Nigeria. We found this in the likeness attitude of the elderly (50–75 years) Nigerian respondents, who have more traditional knowledge about the health benefits of turmeric. This age group could be identified as important in encouraging the consumption of turmeric-fortified drinks.

3.5 Conclusion

This research serves as a starting point for understanding food neophobia among Nigerian consumers in relation to their attitude towards the fortification of familiar street-vended drinks. In this study, Nigerian male university graduates were the most food neophobic. Various instruments are available to measure food neophobia among diverse target groups. The choice of an instrument depends on the scope of the research. The research may be to support the development of plans for the upgrading of foods and to support the introduction of new food products in markets. We recommend further studies in Nigeria to obtain more in-depth knowledge using other instruments such as the Food Eating Questionnaire (FEQ), Food Situation Questionnaire (FSQ), Food Neophobia Scale (FNS), Food Technology Neophobia Scale (FTNS), and Variety Seeking Tendency Scale (VARSEEK).

Specific insights were provided in this study by paying attention to responses from respondents with different demographic characteristics such as age, gender and income. These insights, such as the 46% *vs*. 22% likeness of the turmeric-fortified drinks by 50- to 75-year-old *versus* 26- to 35-year-old respondents, can be of help for African researchers and product developers. In our case, the distinction seems to be due to traditional knowledge of the health benefits of turmeric by the group of senior respondents and the perception of the disgusting properties of herbal medicine ('*agbo*') by the junior respondents. Hence novel food researchers and developers are recommended to study not merely the foods themselves but also the acceptance by their target population.

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Conflict of Interest

The authors have no conflict of interest to declare.

References

1. Nwaekpe J, Anyaegbunam H, Okoye B, Asumugha G. Promotion of turmeric for the food/pharmaceutical industry in Nigeria. Journal of Experimental Agriculture International. 2015;8(6):335-41.

2. Muogbo C, Gbabo A, Nwakuba N. Field performance analysis of a tractor-drawn turmeric rhizome planter. Poljoprivredna tehnika. 2019;44(2):33-46.

3. Hima G, Kaliaperumal K. Turmeric: a condiment, cosmetic and cure. Indian Journal of Dermatology, Venereology & Leprology. 2018;84(1):16-21.

4. Kunnumakkara AB, Bordoloi D, Padmavathi G, Monisha J, Roy NK, Prasad S, et al. Curcumin, the golden nutraceutical: multitargeting for multiple chronic diseases. British journal of pharmacology. 2017;174(11):1325-48.

5. Oyemitan IA, Elusiyan CA, Onifade AO, Akanmu MA, Oyedeji AO, McDonald AG. Neuropharmacological profile and chemical analysis of fresh rhizome essential oil of *Curcuma longa* (turmeric) cultivated in southwest Nigeria. Toxicology reports. 2017;4:391-8.

6. Ibrahim U, Salleh R, Maqsood-ul-Haque S. Bread towards functional food: an overview. International Journal of Food Engineering. 2015;1(1):39-43.

7. Adegoke G, Oyekunle A, Afolabi M. Functional Biscuits from Wheat, Soya Bean and Turmeric (*Curcuma Longa*): Optimization of Ingredients Levels Using Response Surface Methodology. Research Journal of Food and Nutrition. 2017;1(1):13-22.

8. Mahale J, Singh R, Howells LM, Britton RG, Khan SM, Brown K. Detection of Plasma Curcuminoids from Dietary Intake of Turmeric-Containing Food in Human Volunteers. Molecular Nutrition & Food Research. 2018;62(16):1800267.

9. Park SH, Lim HS, Hwang S-Y. Evaluation of antioxidant, rheological, physical and sensorial properties of wheat flour dough and cake containing turmeric powder. Food Science and Technology International. 2012;18(5):435-43.

10. Lim HS, Ghafoor K, Park SH, Hwang SY, Park J. Quality and antioxidant properties of yellow layer cake containing Korean turmeric (*Curcuma longa* L.) powder. Journal of Food & Nutrition Research. 2010;49(3).

11. Maji S, Ray PR, Ghatak PK, Chakraborty C. Total phenolic content (TPC) and quality of herbal lassi fortified with Turmeric (*Curcuma longa*) extract. Asian Journal of Dairy and Food Research. 2018;37(4):273-7.

12. Loewen R, Pliner P. The food situations questionnaire: a measure of children's willingness to try novel foods in stimulating and non-stimulating situations. Appetite. 2000;35(3):239-50.

13. Pliner P, Hobden K. Development of a scale to measure the trait of food neophobia in humans. Appetite. 1992;19(2):105-20.

14. Frank R, van der Klaauw N. The contribution of chemosensory factors to individual differences in reported food preferences. Appetite. 1994;22(2):101-23.

15. Raudenbush B, Schroth F, Reilley S, Frank RA. Food neophobia, odor evaluation and exploratory sniffing behavior. Appetite. 1998;31(2):171-83.

16. Rozin P, Fischler C, Shields C, Masson E. Attitudes towards large numbers of choices in the food domain: A cross-cultural study of five countries in Europe and the USA. Appetite. 2006;46(3):304-8.

17. Flight I, Leppard P, Cox DN. Food neophobia and associations with cultural diversity and socio-economic status amongst rural and urban Australian adolescents. Appetite. 2003;41(1):51-9.

18. MacNicol SA, Murray SM, Austin EJ. Relationships between personality, attitudes and dietary behaviour in a group of Scottish adolescents. Personality and Individual Differences. 2003;35(8):1753-64.

19. Choe JY, Cho MS. Food neophobia and willingness to try non-traditional foods for Koreans. Food Quality and Preference. 2011;22(7):671-7.

20. Muhammad R, Abdullah KM, Zahari MSM, Sharif MSM. Revealing the Scenario of Food Neophobia among Higher Learning Institution Students from Klang Valley, Malaysia. Procedia - Social and Behavioral Sciences. 2015;170:292-9.

21. Vidigal MCTR, Minim VPR, Simiqueli AA, Souza PHP, Balbino DF, Minim LA. Food technology neophobia and consumer attitudes toward foods produced by new and conventional technologies: A case study in Brazil. LWT - Food Science and Technology. 2015;60(2, Part 1):832-40.

22. Martins Y, Pliner P. Human food choices: An examination of the factors underlying acceptance/rejection of novel and familiar animal and nonanimal foods. Appetite. 2005;45(3):214-24.

23. Pliner P, Pelchat M, Grabski M. Reduction of neophobia in humans by exposure to novel foods. Appetite. 1993;20(2):111-23.

24. Frank R, Kalisewicz S. Food experience and willingness to try novel foods. Appetite. 2000;3(34):335.

25. Tuorila H, Lähteenmäki L, Pohjalainen L, Lotti L. Food neophobia among the Finns and related responses to familiar and unfamiliar foods. Food quality and preference. 2001;12(1):29-37.

26. Pliner P, Salvy S. Food neophobia in humans. Frontiers in Nutritional Science. 2006;3:75.

27. Ogunmoyela O, Adekoyeni O, Aminu F, Umunna L. A critical evaluation of survey results of vitamin A and Fe levels in the mandatory fortified food vehicles and some selected processed foods in Nigeria. Nigerian Food Journal. 2013;31(2):52-62.

28. Oyeyinka AT, Oyeyinka SA. *Moringa oleifera* as a food fortificant: Recent trends and prospects. Journal of the Saudi Society of Agricultural Sciences. 2018;17(2):127-36.

29. Akpan I, Muoneke C, Okpara D. Effect of egusi planting density on productivity of egusi/turmeric intercrops in Southeastern Nigeria. Asian Journal of Crop Science. 2013;5(1):41-7.

30. Osawaru M, Eholor R. Ethnotaxonomy and traditional use of turmeric (*Curcuma longa* L.) among some Nigerian tribes in South Edo State, Nigeria. Plant Archives. 2010;10(1):181-9.

31. Adelekan A, Arisa N, Alamu A, Adebayo Y, Popoola G. Production and acceptability of fruits enhanced *zobo* drink. Food Science and Technology Letters. 2014;5(1):046-51.

32. Omemu A, Edema M, Atayese A, Obadina A. A survey of the microflora of *Hibiscus sabdariffa* (Roselle) and the resulting "*Zobo*" juice. African Journal of Biotechnology. 2006;5(3):254-9.

33. Davidson GI. Nutrient content and sensory evaluation of hawked and home-made Roselle (*Zobo*) drink. Journal of Home Economics Research. 2011;15:209-18.

34. Adesokan I, Abiola O, Adigun M, Anifowose O. Analysis of quality attributes of *Hibiscus sabdariffa* (*zobo*) drinks blended with aqueous extract of ginger and garlic. African Journal of Food Science. 2013;7(7):174-7.

35. Obadina A, Akinola O, Shittu T, Bakare H. Effect of natural fermentation on the chemical and nutritional composition of fermented soymilk *nono*. Nigerian food journal. 2013;31(2):91-7.

36. Adeniji P. Nutritional, Sensory and Microbiological Quality Assessment of fortified *Zobo* Drink: A Home-Prepared Traditional Nigerian Beverage. J Nutr Food Sci. 2017;7(627):2.

37. Brooks A, Asamudo N, Udoukpo F. Microbiological and physico-chemical analysis of soymilk and soyflour sold in Uyo metropolis, Nigeria. Global Journal of Pure and Applied Sciences. 2003;9(4):457-64.

38. Cirkovic Velickovic TD, Stanic-Vucinic DJ. The Role of Dietary Phenolic Compounds in Protein Digestion and Processing Technologies to Improve Their Antinutritive Properties. Comprehensive Reviews in Food Science and Food Safety. 2017;17(1):82-103.

39. Izah SC, Orutugu LA, Kigigha LT. A review of the quality assessment of *zobo* drink consumed in Nigeria. ASIO Journal of Microbiology, Food Science and Biotechnology Innovations. 2015;1(1):34-44.

40. Gana IM. Design, fabrication and testing of soya milk production and pasteurization mini plant. Agricultural Engineering International: CIGR Journal. 2018;19(4):45-53.

41. Ezeigbo O, Uhiara S, Nwodu J, Ekaiko M. Bacteriological assessment of hawked sorrel drink (*zobo* drink) in Aba, South-East Nigeria. British Microbiology Research Journal. 2015;5(2):146-51.

42. Omeremu DM, Enoch AS, Azuonwu O. Bacteriological Quality Assessment of *Zobo* Drink Sold in Bayelsa State Nigeria. Journal of Applied Life Sciences International. 2019:1-8.

43. Damsbo-Svendsen M, Frøst MB, Olsen A. A review of instruments developed to measure food neophobia. Appetite. 2017;113:358-67.

44. Alley TR, Reilly S. Conceptualization and measurement of human food neophobia. Food Neophobia: Woodhead Publishing; 2018:69-92.

45. Maiz E, Balluerka N, Maganto C. Validation of a questionnaire to measure the willingness to try new foods in Spanish-speaking children and adolescents. Food Quality and Preference. 2016;48:138-45.

46. Nepote V, Olmedo RH, Mestrallet MG, Grosso N. A study of the relationships among consumer acceptance, oxidation chemical indicators, and sensory attributes in high-oleic and normal peanuts. Journal of Food Science. 2009;74(1):S1-S8.

47. Yang J, Lee J. Korean consumers' acceptability of commercial food products and usage of the 9-point hedonic scale. Journal of sensory studies. 2018;33(6):e12467.

48. NBS. Final Statistical Report. National Bureau of Statistics. 2007;1:420.

49. Eze TC, Okpala CS, Ogbodo JC. Patterns of inequality in human development across Nigeria's six geopolitical zones. Dev Country Stud. 2014;4(8):97-101.

50. Alozie YE, Ene-Obong HN. Recipe standardization, nutrient composition and sensory evaluation of waterleaf (*Talinum triangulare*) and wild spinach (*Gnetum africanum*) soup "afang" commonly consumed in South-south Nigeria. Food chemistry. 2018;238:65-72.

51. Uwaifo V, Uddin P. Transition from the 6-3-3-4 to the 9-3-4 system of education in Nigeria: An assessment of its implementation on technology subjects. Studies on Home and Community Science. 2009;3(2):81-6.

52. Ogundele AR, Ogunniran MO, Abanikannda M. Challenges of Educational Technology and Adequacy of Trained Educator for the Implementation of Universal Basic Education (UBE) Program in Primary Schools: A Case of Ondo State, Nigeria. International Journal of Social Sciences and English Literature. 2019;3:12-25.

53. Nworgu BG, Nworgu LN. Urban-rural disparities in achievement at the basic education level: The plight of the rural child in a developing country. Developing Country Studies, 2013;(14), 128–140.

54. Stratton LM, Vella MN, Sheeshka J, Duncan AM. Food neophobia is related to factors associated with functional food consumption in older adults. Food quality and preference. 2015;41:133-40.

55. Olabi A, Najm NEO, Baghdadi OK, Morton JM. Food neophobia levels of Lebanese and American college students. Food Quality and Preference. 2009;20(5):353-62.

56. Adewunmi F. Nigeria's Middle-class: How We Live, and What We Want from Life. How We Made It In Africa. 2011;Retrieved from https://www.howwemadeitinafrica.com/nigerias-middle-class-how-we-live-and-what-we-want-from-life/12563/.

57. Ifeanyichukwu CD. Effect of celebrity endorsements on consumers purchase decision in Nigeria. International research journal of management, IT and social sciences. 2016;3(9):120-8.

58. Adegoju A. A rhetorical analysis of the discourse of advertising herbal medicine in southwestern Nigeria. Linguistik online. 2008;33(1/80):1-16.

59. Martini S, Conte A, Tagliazucchi D. Comprehensive evaluation of phenolic profile in dark chocolate and dark chocolate enriched with Sakura green tea leaves or turmeric powder. Food Research International. 2018.

60. Wahanik AL, Neri-Numa IA, Pastore GM, Chang YK, Clerici MTPS. Turmeric (Curcuma longa L.): new application as source of fiber and antioxidants in pasta with whole wheat flour. Magazine of the National Faculty of Agronomy, Medellín. 2018;71(1):8423-35.

61. Verbeke W. Consumer acceptance of functional foods: socio-demographic, cognitive and attitudinal determinants. Food quality and preference. 2005;16(1):45-57.

CHAPTER 4

Enriching street-vended zobo (*Hibiscus sabdariffa*) drink with turmeric (*Curcuma longa*) to increase its health-supporting properties

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Abstract

Street-vended foods are cheap, readily available and have been currently identified as possible means for micronutrient fortification in an effort to prevent malnutrition in developing countries. The effect of enriching street-vended *zobo* drink (*Hibiscus sabdariffa*) with turmeric (*Curcuma longa*) was studied to assess the potential to increase health-supporting properties for its consumers. Two processing methods were tested: boiled turmeric root in *zobo* and addition of fresh turmeric paste to *zobo* in different concentrations. Vitamin C in turmeric-fortified *zobo* ranged from 496–725 µg per 100 mL, delphinidin-3-sambubioside from 52–69 mg per 100 mL, and cyanidin-3-sambubioside from 21–27 mg per 100 mL. Micronutrients ranged from 10.9–14 mg L^{-1} and 2.19–2.67 mg L^{-1} for iron and zinc, respectively. Folic acid, vitamin C, anthocyanins and iron showed the highest amounts in the 2% boiled turmeric *zobo* samples. Ferulic acid (0.16–2.03 mg per 100 mL), and chlorogenic acid (20–24 mg per 100 mL) did not show the same statistically significant improvement for 2% boiled turmeric-fortified *zobo*. The *zobo* samples with turmeric paste consistently had lower values of vitamins, polyphenols, and minerals in comparison with the boiled turmeric-fortified *zobo* samples. Turmeric-fortified *zobo* can play a role in a healthy diet by its health-supporting properties. Consumption of a typical one serving of 500 mL (representative packaged bottle size of *zobo* drink by the street vendors in Nigeria) of turmeric-fortified *zobo* would contribute 63–88% DV and 18–23% DV of iron and zinc. Overall, fortification with boiled turmeric improves the antioxidant and nutritional quality of *zobo*, specifically regarding vitamin C, delphinidin-3-sambubioside and iron.

Keywords: Ferulic acid, micronutrient, fortification, antioxidant, vitamins, polyphenols

4.1 Introduction

Street foods provide a high percentage of daily energy, ranging from 13% to 50% in both children and adults, in developing countries.[1] A popular street food drink produced and sold in Nigeria is *zobo*, which is produced from dried hibiscus (*Hibiscus sabdariffa* L.) calyces, and optional flavourings such as garlic, ginger, and fruit.[2] Similar to fruit juices, *zobo* is commonly consumed for its affordability, nutritive value and refreshing quality. Hibiscus is an underutilised crop grown in Africa, Asia, Australia, Central America, and Europe.[3] In English, it is commonly known as roselle and has various local names depending on the continent. In Africa, Burkina Faso, Côte d'Ivoire, and Mali, it is referred to as *dabileni*. It is known as *karkade* in Sudan and Egypt (where it is also called the "*drink of the Pharaohs*"). It is commonly known as *karkanji*, *wonjo*, *zobo* and bissap in Chad, Gambia, Nigeria and Senegal, respectively. In Asia, it is named *mei gui qie*, *karkade* and *krajeap* in China, Saudi Arabia and Thailand, respectively. It is recognized as *asam belanda*, *asam susur*, *asam paya* or *ribena*, in Malaysia. The Indian subcontinent calls it by many tribal names such as *Indian sorrel*, *mesta*, *lal ambari*, *patwa*, *amta* and *amti*. It is known as *rosella* in Australia and *flor de Jamaica* in Mexico. In Europe, it is referred to as *Congo*, *Jamaica* and *karkade* in France, Spain, and Switzerland, respectively.[3–6] The many names for this crop reflect its ubiquity and popularity.

Scientific studies have revealed that *zobo* calyces are rich in flavonoids, minerals, organic acids, vitamins, and polyphenol compounds, which all contribute to the nutritive value and biological activity of the drink.[7–9] The two major anthocyanin compounds in *H. sabdariffa* calyces are delphinidin-3-sambubioside and cyanidin-3-sambubioside. These anthocyanins have been reported as unstable and likely to degrade during the preparation of the drink. However, processing conditions such as extraction temperature, protection from UV light, and the addition of food-grade organic acid have been reported to impact anthocyanin stability.[10] A recent study characterized the physicochemical properties and non-volatiles of *H. sabdariffa* calyces cultivated in Australia, China, Chad, Malaysia, Mexico, Nigeria, Sudan and Thailand.[3] They concluded that variations found in the characterization of the *H. sabdariffa* calyces grown in different countries were mainly due to the practice of sun drying. Sun drying is a traditional processing method to obtain dried *H. sabdariffa* calyces that are easy to transport and store in developing countries, including Nigeria.

Due to *zobo*'s popularity, any nutritional improvement of the drink is likely to benefit many people in Nigeria, where malnutrition is a major concern.[11] One approach to further augment *zobo* would be through food-to-food fortification, which is a solution for the population without radically changing food consumption patterns.[12] Fortification of the *zobo* drink with another food ingredient that is rich in bioactive compounds could also improve the stability of the anthocyanin content, based on reports that the structure of the organic acid and food matrix in which it is combined would have a strong effect on the stability of the anthocyanins.[10]

Turmeric (*Curcuma longa*) can be used in *zobo* to fortify and potentially improve the antioxidant and nutritional quality of the drink. It is a shallow-rooted crop that is commonly grown throughout Nigeria, making its production and sales regionally and economically beneficial.[13] Turmeric contains curcumin, a well-known polyphenol with many acclaimed health benefits in addition to anti-inflammatory and antioxidant properties that have been researched extensively.[14] In addition to curcumin, turmeric has been found to contain other antioxidants, such as ferulic acid.[15] Ferulic acid exhibits anti-inflammatory, antidiabetic, and anticancer activity. In addition, ferulic acid has protective effects on organs, tissues, and cells of the cardiovascular system and skin.[16]

In this study, turmeric was added to *zobo* in different concentrations using two processing methods: boiling of turmeric root in the *zobo* and addition of fresh turmeric paste to the final *zobo* drink. The research aimed at determining if the addition of turmeric could improve the antioxidant and nutritional profile of the *zobo* drink. Overall, the effect of processing on the antioxidant and nutritional quality of turmeric-fortified zobo was established.

4.2 Materials and methods

Materials

Food ingredients: Dried *zobo* (*H. sabdariffa*) calyces were purchased from Dutse market, Abuja, Nigeria. Turmeric roots were purchased from Omuooke-Ekiti market, Ekiti State, Nigeria.

Chemical: Ascorbic acid, folic acid, chlorogenic acid, and trans-ferulic acid were purchased from Sigma Aldrich (St Louis, MO, USA). Delphidin-3-sambubioside chloride and cyanidin-3-sambubioside chloride were purchased from Extrasynthese (France). All solvents in the experiments were HPLC grade.

Sample preparation

Preparation of turmeric paste: Turmeric paste was made by combining 40 g of finely chopped turmeric root (Fig. 4.1a) with 80 mL of tap water. The two components were blended, using a Waring Commercial blender (United States), for approximately four min at the highest speed, until smooth. The final product can be seen in Fig. 4.1b.

Preparation of controls: Five control samples were produced: the turmeric controls consisted of turmeric in water, using two different preparation methods and two different concentrations. The first method consisted of boiling water with chopped turmeric root pieces (Fig. 4.1a) of approximately 2 × 2 mm for five min. The turmeric pieces were allowed to soak in the water overnight, followed by sieving in the morning. The second method consisted of boiling water and allowing the water to cool overnight. The following morning, fresh turmeric paste was added and stirred. Both methods included utilising turmeric at two different concentrations, 2% and 6% based on the weight of the water during the addition: water with boiled turmeric 2% w/w, water with boiled turmeric 6% w/w, water with fresh turmeric paste 2% w/w, and water with fresh turmeric paste 6% w/w. The *zobo* control was prepared by boiling water and *H. sabdariffa* calyces, in a ratio of 2:25 by weight, in a large pot for five min. The pot was then removed from the heat source and allowed to soak overnight. Next, the beverage was sieved. The final beverage samples are shown in Fig. 4.1c.

Preparation of turmeric-fortified *zobo* samples: Four turmeric-fortified *zobo* samples were produced: *zobo* with boiled turmeric 2% w/w, *zobo* with boiled turmeric 6% w/w, *zobo* with fresh turmeric paste 2% w/w, and *zobo* with fresh turmeric paste 6% w/w. The turmeric-fortified *zobo* samples were all prepared with water and *H. sabdariffa* calyces, in a ratio of 2:25 by weight. The *zobo* with boiled turmeric was prepared by boiling *H. sabdariffa* calyces with finely chopped turmeric root pieces for five min, followed by soaking at room temperature overnight and sieving in the morning. The turmeric pieces were added at either 2% or 6% of the weight of the water during the addition. The *zobo* with fresh turmeric paste was made using the same method as the *zobo* control, but with the addition of either 2% or 6% turmeric paste after the overnight soak and sieving. A schematic representation is presented in Fig. 4.2.

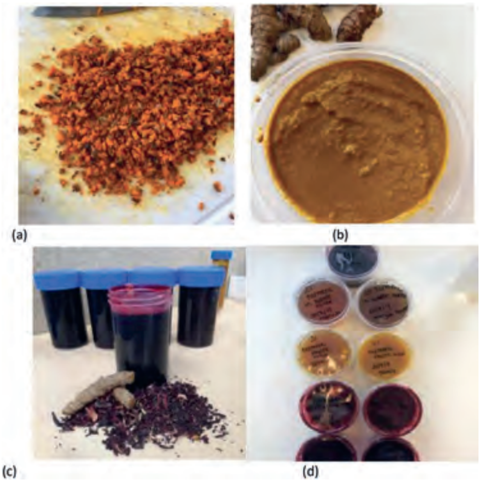

Fig. 4.1: (a) Chopped turmeric for boiled turmeric samples. (b) Freshly blended turmeric for turmeric paste samples. (c) and (d) Final samples ready for analysis.

Freeze drying: Samples were freeze-dried for 140–144 h in a freeze-dryer (Martin Christ Gefriertrocknungsanlagen GmbH), until all moisture was evaporated. The sample was weighed before and after freeze-drying to accurately calculate original values.

Chemical analysis

Measurement of pH: The pH of the *zobo* samples was measured with a pH meter (pHenomenal VWr pH 1000 L).

Proximate analysis

Moisture content: The moisture content was determined following the method described by Ekanem.[17]

Ash content: The ash content was measured by heating the sample in a Carbolite CSF1100 ashing oven at 550 °C for 6 h, after the method of Ekanem.[17]

The ash content was calculated with the formula below:

$$Ash\ content = \frac{Weight\ of\ the\ sample\ after\ ashing}{Weight\ of\ the\ sample\ transferred\ before\ ashing} \times 100\%$$

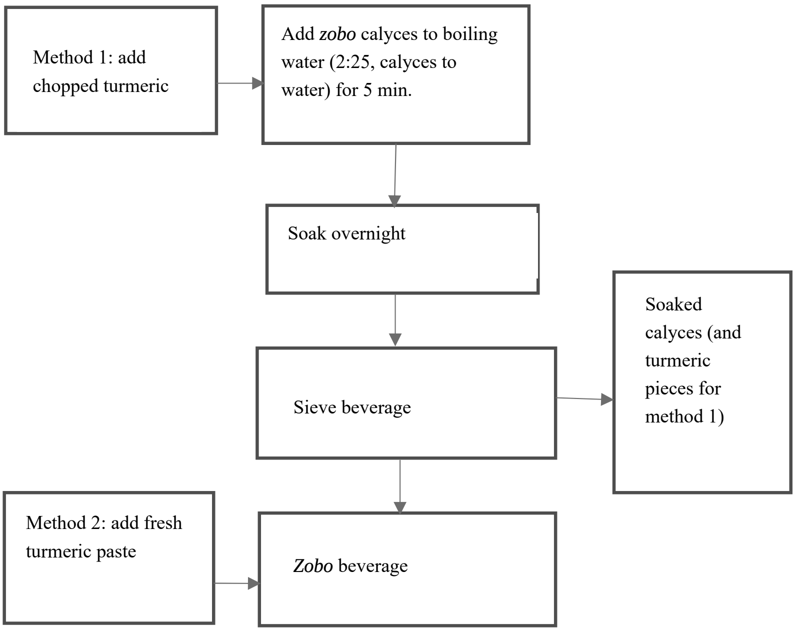

Figure 4.2: *Zobo* production flow scheme for the two methods of the study

Crude protein content: The protein content was analysed using LECO CN 628 Dumas analyser, Germany. Freeze-dried samples and blank samples with cellulose (Sigma Aldrich 310697, US) were weighed in tin cups (Interscience, Belgium) and put in a sample tray. The samples were then oxidised in the Dumas metal column filled with chemicals at high temperatures and water filters in a separation column, on which nitrogen was separated and calculated into protein content. The standard nitrogen to protein conversion factor, 6.25, was used to calculate the protein concentration.[18]

As all food fractions should add up to 100%, the carbohydrate content was calculated by the formula: [17]

$$\begin{aligned} &Carbohydrate\ content \\ &\quad = 100\% - moisture\ content - ash\ content - fat\ content \\ &\quad - crude\ protein\ content \end{aligned}$$

Mineral determination: Mineral (iron and zinc) analysis was performed at the Chemisch Biologisch Laboratorium Bodem (CBLB), Wageningen, the Netherlands, according to the procedure described in the plant analysis procedure. [19] Samples were destructed with HNO_3–HCl (aqua regia) and measured with the ICP-AES method for iron and zinc.

Vitamin determinations

Folic acid: Folic acid concentration was determined by HPLC as described by Chen et al.[20] A Thermo Scientific (Germany) Ultimate 3000 HPLC machine with an RS diode array detector was used. Modifications made were: folic acid standards were prepared in KH_2PO_4 buffer at pH 8–9. Alltech prevails C18 5u column (4.6 × 250 mm) was used. The samples were prepared by sonication of freeze-dried samples for 5 h at 40 °C. Centrifugation followed at 4000 rpm for seven min. Samples were then filtered into amber HPLC vials. Quantification based on measurement of peak areas was taken with UV detection at 283 nm for 25 min.

Vitamin C: Ascorbic acid was determined as described by Hernández et al. [21] using a Thermofisher HPLC (Thermo Scientific, Germany). The samples containing *zobo* were diluted twice, while samples containing just water and turmeric were not diluted. A Varia Polaris 5 C18-A column (4.6×150 mm) was used.

Anthocyanin determinations

Delphidin-3-sambubioside and cyanidin-3-sambubioside: Delphidin-3-sambubioside and cyanidin-3-sambubioside were determined using HPLC (Thermo Scientific, Germany). *Zobo* samples were prepared according to the previously mentioned protocol in preparation of turmeric-fortified *zobo* samples. The *zobo* and water samples were extracted using 0.1% HCl in methanol. 5 mL of sample was combined with 5 mL of extraction liquid in a 15 mL greiner tube and shaken for one h at maximum speed. All samples were then centrifuged at 3000 rpm for 30 min. Next, samples were filtered using 0.45 µm RC filters into amber HPLC vials. HPLC analysis utilised 1% formic acid in Milli-Q® water as eluent A and 100% methanol as eluent B. The gradient elution started with 5% (B), which increased to 60% (0–20 min) and then to 100% (20–25 min). The conditions were held at 100% for 5 min prior to returning to 5% (30–31 min) with a final isocratic run of 5% B (31–35 min). The flow rate was 1 ml min^{-1} and the injection volume was 20 µl. A Varian Polaris 5 C18-A column (5 µm, 4.6 × 150 mm) was used. Calibration curves for both delphidin-3-sambubioside and cyanidin-3-sambubioside were made by making a stock solution of 1 mg mL^{-1} in methanol. The stock solutions were stored at −20 °C. The calibration curve consisted of seven calibration standards: 17.19–34.38–68.75–137.5–275–550 (µg ml^{-1}) of delphidin-3-sambubioside and cyanidin-3-sambubioside. The UV-Vis spectrum of 510 nm was used for analysing data from chromatograms.

Chlorogenic and ferulic acid determinations

Six samples including all *zobo* containing samples and water with boiled turmeric at both 2% and 6% were analysed. Chlorogenic acid and ferulic acid were determined using the method described by Beltrán-Debón et al. [22] An Ultimate 3000 HPLC machine (Thermo Scientific, Germany) with an RS diode array detector was used. Modifications made were: a Varian Polaris 5 C18-A 4.6 × 150 mm column was used at a flow rate of 1 ml min^{-1}. Stock solutions of 1 mg ml−1 were made for chlorogenic acid and ferulic acid and stored at −20 °C. A calibration curve for each component was prepared with six work solutions: 4.69–9.38–18.75–37.5–75–150 (μg mL^{-1}). Fresh, liquid *zobo* samples were used and diluted two times with Milli-Q® water/trifluoroacetic acid pH 2.5 before filtering. UV-Vis spectrum was recorded at the wavelength of 220 nm for both chlorogenic acid and ferulic acid.

Statistical analysis

Data were analysed using Microsoft Office 2016, Chromeleon 7 and IBM SPSS Statistics. Analysis was performed in triplicate with three independent batches for all samples except otherwise stated. The differences between the samples were determined using paired t-tests between batches of the same sample and assumed equal variance t-tests (two-sample) between different sample means. To determine if data were normally distributed, the test of Shapiro–Wilk was used with $p < 0.05$, where H_0 = data is normally distributed and H_a = data is not normally distributed.

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4.3 Results and discussion

pH: The pH of the *zobo* was measured to determine the amount of acid, which influences vitamin stability and measurements. The pH of *zobo* slightly increased with increasing turmeric concentration and ranged between 2.4–2.6. The addition of turmeric increased the pH and higher concentrations of turmeric paste increased the pH further (Table 4.1). A higher pH, namely 3.6, was found by Ekanem[17] using a lower ratio of hibiscus calyces (1.5:25). Furthermore in his study, the *zobo* was boiled for a longer time (40 min) and not soaked overnight. This could influence the composition of the extracts, thus influencing the pH. Adesokan et al. [23] reported an even higher pH of 3.94. Their preparation method used a ratio of 15:25, much higher than the ratio used in this research. Additionally, the calyces were added to boiling water and only allowed to soak for 15 min. Consequently, the higher pH in the literature might be due to the shorter time the hibiscus calyces were kept in the water. Letting the *zobo* soak overnight allows for a longer extraction time, in which more acid compounds might be dissolved, thus resulting in the lower pH found in our study. The slight increase in pH by adding turmeric to *zobo* is unlikely to significantly affect product properties.

Proximate composition

Moisture content: The moisture content of the zobo control found in our study (Table 4.1) was in accordance with values found by Adeniji et al. [24] who measured the moisture content of commercial (95.1% moisture) and locally prepared (94.5% moisture) *zobo*. However, other authors reported lower moisture contents, in the range of 82–88%.17,25 The higher dry matter content they found could be due to the addition of flavouring ingredients, such as ginger and fruits, or sugar.

Ash content: For the ash content, values between 0.6–1.8% were reported in the literature.[24–26] The ash content in this study is slightly lower than this range, which can be explained by the moisture content of the *zobo*. Turmeric in water control samples contained 0.03–0.06% ash with 6% fresh turmeric paste in water having the highest value. However, *zobo* with boiled turmeric 2% and 6% had higher ash contents than the *zobo* control and the 2% and 6% fresh turmeric paste in *zobo*. This implies that boiled turmeric samples would have higher mineral contents[18] and this was also proven in this present study as the highest values of iron and zinc were recorded in 2% and 6% boiled turmeric in *zobo*, respectively. Moreover, turmeric has been reported to contain a low ash content, namely 2.9%. Other medicinal plants contain higher ash contents, such as *Acalypha racemosa* (13.1%) and *Acalypha marginata* (10.3%).[27]

Crude protein content: A low protein content was found in this study (Table 4.1). However, the addition of turmeric seemed to increase protein content. Turmeric contains 6.3% protein,[28] which is much higher than the amount of protein found in the *zobo* control. This was reflected in the *zobo* with boiled turmeric samples (2% and 6%), which contain significantly more protein than the *zobo* control.

Mineral content

Iron and zinc deficiencies are globally predominant, classified 9th and 11^{th,} respectively, in the category of the main risk factors for the worldwide problem of ailment and they mostly occur in developing nations.[29] The amount of iron and zinc in the water used for *zobo* preparation was negligible: −0.01 and 0.02 mg L^{-1} for iron and zinc, respectively. The iron and zinc in the turmeric-fortified *zobo* were from both the hibiscus calyces and turmeric.

Table 4.1: pH and proximate composition (weight %) of *zobo* control and turmeric-fortified *zobo*

Samples	pH	Moisture	Ash	Protein	Carbohydrates*
Control (*zobo* with 0% turmeric)	2.4 ± 0.01^{B}	96.2 ± 0.29^{A}	0.47 ± 0.03^{A}	0.18 ± 0.01^{B}	3.1
2% boiled turmeric in *zobo*	2.4 ± 0.03^{ABC}	95.9 ± 0.45^{AB}	0.54 ± 0.06^{A}	0.23 ± 0.01^{A}	3.4
6% boiled turmeric in *zobo*	2.6 ± 0.02^{AC}	95.8 ± 0.18^{AB}	0.56 ± 0.06^{A}	0.22 ± 0.01^{A}	3.4
2% fresh turmeric paste in *zobo*	2.4 ± 0.01^{C}	95.9 ± 0.15^{AB}	0.45 ± 0.04^{A}	0.18 ± 0.03^{AB}	3.5
6% fresh turmeric paste in *zobo*	2.5 ± 0.02^{A}	95.8 ± 0.24^{B}	0.47 ± 0.05^{A}	0.20 ± 0.04^{AB}	3.5

Significant differences ($p < 0.05$) in the same column are indicated with different superscripts *The carbohydrate content was calculated from the other fractions to have an indication of the carbohydrate content of our samples.

The average amounts of iron and zinc in our samples ranged between 10–14 mg L^{-1} and 2.1–2.7 mg L^{-1}, respectively with the highest values of iron and zinc recorded in 2% and 6% boiled turmeric in *zobo* respectively. These ranges are within the interval reported in the literature.[30,31] In children aged 2 to 5 years, the daily recommended intake of iron is 8 mg and the daily recommended intake of zinc is 6 mg.[32,33] Consumption of a typical one serving of 500 mL (representative packaged bottle size of *zobo* drink by the street vendors) of turmeric-fortified *zobo* would contribute 63–88% DV and 18–23% DV of iron and zinc respectively. In agreement with the recent literature[34] on the use of nutrition information and understanding of percentage Daily Value (DV) based on the health Canada campaign message ("5% DV or less is a little; 15% DV or more is a lot"), thus, drinking turmeric-fortified *zobo* would contribute significantly towards the required intake of iron and zinc.

Vitamins

Vitamin B_9, or folate, is synthetically produced as folic acid for food fortification and supplementation. Folic acid was detected in all samples containing *zobo*, whereas no folic acid was found in the turmeric in water samples. Folic acid ranged from 256–301 µg per 100 mL (Table 4.2). The Recommended Dietary Allowance (RDA) for adults is 400 µg day^{-1}, with pregnant and lactating women needing an additional 100–200 µg day^{-1}.[35] Further 400 µg day^{-1} of synthetic folic acid from either supplements or fortified foods is recommended for females capable of becoming pregnant to lessen the risk of neural tube defects (NTD).[36] Drinking turmeric-fortified *zobo* would contribute in excess to the recommended daily intake of folic acid as one serving contains 320–376% DV, 213–251% DV and 160–188% DV for adults, lactating and women capable of becoming pregnant recommended daily intake respectively. *Zobo* is usually sold by street vendors in 500 mL bottles in Nigeria. Hence, drinking a half bottle (250 mL) is enough to exceed the daily required amount of folic acid for all ages and genders. Adequate daily intake of folic acid is important to prevent neural tube defects, which are four times more likely to occur in developing countries, such as Nigeria, than in developed countries.[37]

Vitamin C was measured as the total amount of ascorbic acid. The four control samples containing turmeric in water resulted in no detectable peaks, corroborating that turmeric does not contain ascorbic acid.[38] The amount of vitamin C in the samples ranged from 496–725 µg per 100 mL (Table 4.2). Samples fortified with 6% turmeric paste had the lowest value with no significant difference with the *zobo* boiled with 6% turmeric root. However, the value found in the control sample (0% turmeric) was lower than in other scientific articles, which ranged from 1500–3000 µg per 100 mL.2,[39] The difference in vitamin C content could be due to the process applied to dry the *H. sabdariffa* calyces used for the production of the *zobo*, as vitamin C can be lost through heating.[40] Additionally, the quantity of *H. sabdariffa* calyces used for the production of *zobo* also has an effect, as research has shown that vitamin C content increases when the amount increases from 2% calyces to 15% calyces in water.[39]

In this study, the quantity of *H. sabdariffa* calyces used in *zobo* was 8%. According to the previous research, increasing *H. sabdariffa* calyces above the 8% used in our study could increase the total ascorbic acid content. The vitamin C content in the sample with 2% boiled turmeric in *zobo* was significantly higher than in all other samples, showing a similar pattern as for the anthocyanin in the samples (Table 4.2). Ascorbic acid was not detectable in the four control samples containing turmeric in water. The highest value reported in 2% boiled turmeric in *zobo*, which was significantly different from the control (*zobo* with 0% turmeric), could be attributed to the effect of food-to-food fortification,[41] as the effect of a bioactive may differ between the whole food (matrix effect) and the isolated compound.[42,43]

Table 4.2: Polyphenols, anthocyanins and vitamins contents in turmeric-fortified *zobo* and water samples

Samples	Ferulic acid (mg/100 mL)	Chlorogenic acid (mg/100 mL)	Cyanidin-3-sambubioside (mg/100 mL)	Delphinidin-3-sambubioside (mg/100 mL)	Folic acid (µg/100 mL)	Ascorbic acid (µg/100 mL)
Control (*zobo* with 0% turmeric)	1.9 ± 0.6^{C}	22.3 ± 2.1^{AB}	23.0 ± 5.4^{A}	58.1 ± 13.3^{A}	295 ± 36AB	577 ± 59A
2% boiled turmeric in *zobo*	1.5 ± 0.1^{C}	24.1 ± 3.3^{A}	26.9 ± 0.9^{B}	68.8 ± 2.2^{B}	301 ± 37A	725 ± 84B
6% boiled turmeric in *zobo*	1.5 ± 0.3^{C}	22.7 ± 1.9^{AB}	24.2 ± 1.8^{A}	60.3 ± 5.1^{A}	297 ± 27A	535 ± 146AC
2% fresh turmeric paste in *zobo*	2.0 ± 0.8^{C}	21.1 ± 1.2^{BC}	22.1 ± 5.4^{A}	55.6 ± 12.9^{A}	256 ± 51B	533 ± 48A
6% fresh turmeric paste in *zobo*	1.8 ± 0.6^{C}	20.0 ± 1.4^{C}	20.6 ± 5.1^{A}	52.2 ± 12.6^{A}	276 ± 87AB	496 ± 75C
2% boiled turmeric in water	0.2 ± 0.1^{A}	ND	NA	NA	ND	ND
6% boiled turmeric in water	0.7 ± 0.3^{B}	ND	NA	NA	ND	ND
2% fresh turmeric paste in water	ND	ND	NA	NA	ND	ND
6% fresh turmeric paste in water	ND	ND	NA	NA	ND	ND

Different letters represent significant differences within the same column ($p < 0.05$) *ND represents Not Detected and NA represents Not Applicable

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Research has also shown that heat treatment, such as boiling, can release bound antioxidant principles from turmeric, resulting in higher ascorbic acid content.[44] Other studies, focusing on curcumin, have suggested that the activity following the heating step could be a result of the degradation products, which provide similar activity.[45] Vitamin C contents in 6% boiled turmeric in *zobo* appeared to be significantly lower than the vitamin C content found in 2% boiled turmeric in *zobo*, which we suspect to be due to aggregation and/or precipitation at a higher concentration. The recommended intake for vitamin C is 75 mg for women and 90 mg for men.[46] For children, the RDA is 40 mg, which is necessary to prevent wasting in Sub-Saharan Africa.[47] The vitamin C content in one serving (one bottle of 500 mL) of the 2% boiled turmeric *zobo* could moderately34 contribute 5% DV, 4% DV and 9% DV for women (75 mg), men (90 mg) and children (40 mg) recommended intake respectively. The addition of fruit juices, common in *zobo* processing, could increase the overall content of vitamin C.[2]

Anthocyanins

Cyanidin-3-sambubioside has been identified as one of the two major anthocyanin components of *H. sabdariffa*.[3,10] However, it has not been determined if the addition of turmeric affects the anthocyanin content. Cyanidin-3-sambubioside was present in all *zobo* samples in a range of 21–27 mg per 100 mL (Table 4.2). It accounts for approximately 30% of the total anthocyanin content in turmeric-fortified *zobo*, which is similar to values reported in previous research. An increase in the amount of calyces used for production and boiling time of the turmeric-fortified *zobo* beverage could potentially result in higher quantities of total anthocyanins found in this study. Turmeric-fortified *zobo* processed with 2% boiled turmeric is significantly higher in Cyanidin-3-sambubioside than all other samples. This is in line with the theory explained in the vitamin C section, stating that heat treatment of turmeric can impact other compounds. As turmeric alone contains no anthocyanins, heat treatment cannot release bound anthocyanin principles. Rather, the heat treatment can result in degradation products that act similarly to anthocyanins.[45]

Delphinidin-3-sambubioside is the other primary anthocyanin in *H. sabdariffa*.[3,10] Delphinidin-3-sambubioside in the turmeric-fortified *zobo* is present in a range of 52–69 mg per 100 mL (Table 4.2). Delphinidin-3-sambubioside constitutes approximately 70% of the total anthocyanins, across all samples. This result correlates with previous research, which has shown that delphinidin-3-sambubioside accounts for between 75–85% of the total anthocyanins in *zobo*.[48,49] The effect of turmeric processing has similar outcomes for both delphinidin-3-sambubioside and cyanidin-3-sambubioside. The highest amount of delphinidin-3-sambubioside was recorded for 2% boiled turmeric in *zobo*, as 69 mg per 100 mL was significantly higher than the contents of all other samples. In fresh calyces of *H. sabdariffa*, both delphinidin-3-sambubioside and cyanidin-3-sambubioside have concentrations more than double of that found in the turmeric-fortified *zobo* beverage. [48]

The significant loss of anthocyanins is most likely due to heat degradation during drying.[50] Juhari et al.[3] confirmed that variation in the anthocyanin content of *H. sabdariffa* calyces grown in different countries was mainly due to sun drying. The addition of food-grade organic acids has been reported to improve anthocyanin stability.[10] These findings were corroborated by the increase in the anthocyanin content of the 2% boiled turmeric *zobo*. This increased amount of anthocyanins could contribute to the anti-inflammatory, visual and neurological-health improving properties of turmeric-fortified *zobo*.[51,52]

Ferulic and chlorogenic acid

H. sabdariffa contains several polyphenols: chlorogenic acid, hydroxycitric acid, protocatechuic acid, quercetin, ferulic acid, and caffeic acid.[22,53,54] In an exploratory trial at the beginning of this study, the peaks with the largest area were determined to identify the polyphenols present in the highest concentrations. The polyphenols analysed via HPLC for identification were: caffeic acid, ferulic acid, protocatechuic acid, gallic acid, quercetin, catechin, rutin, naringin, benzoic acid, and chlorogenic acid. Five major peaks (Fig. 4.3) were consistently found in either zobo or boiled turmeric in water, namely ferulic acid, chlorogenic acid, two anthocyanin peaks, and a major polyphenol peak that remained unknown. The anthocyanin peaks. were characterized by their high UV maximum (515 nm). These peaks were identified as cyanidin-3-sambubioside and delphinidin-3-sambubioside. The two other main peaks were phenolic acids, namely ferulic acid and chlorogenic acid.

<u>Ferulic acid:</u> Ferulic acid was detected in seven samples, in a range of 0.16–2.03 mg per 100 mL (Table 4.2), including those samples in which turmeric was added to water. These results agree with previous research that states that ferulic acid is present in turmeric, as a major decomposition product of curcumin.[15,38] The absence of ferulic acid in the fresh turmeric paste in water samples is attributed to the absence of heat treatment. Ferulic acid is typically formed after the thermal degradation of curcumin.[15]

The *zobo* and the turmeric-fortified *zobo* did not differ in the quantities of ferulic acid they contained. This demonstrates that turmeric, whether boiled or in paste form, does not affect the total ferulic acid in turmeric-fortified *zobo* in the quantities that we tested. The only two samples with significantly lower amounts were the water samples with boiled turmeric. Yet, when 6% of turmeric was added instead of 2%, the total ferulic acid content significantly increased. This shows that more heat degradation products are formed with a higher amount of added turmeric. According to Vankar et al.,[44] the boiling of turmeric could potentially release bound antioxidant principles, which could allow for a detectable amount of ferulic acid.

Other research has also shown that total phenolic content can increase after heat treatment due to the inactivation of polyphenol oxidase.[55] This supports the findings that turmeric paste in water has no detectable ferulic acid or phenolics. In the *zobo* samples, most of the ferulic acid originated from *H. sabdariffa*, making the differences between boiled turmeric and turmeric paste insignificant. The processing of turmeric had no impact on the overall ferulic acid content, making the addition of turmeric not an extra source of ferulic acid in *zobo*.
Chlorogenic acid. Chlorogenic acid only was present in samples containing *H. sabdariffa*, in line with previous research.[22,31] The range of chlorogenic acid is approximately 20–24 mg per 100 mL (Table 4.2).

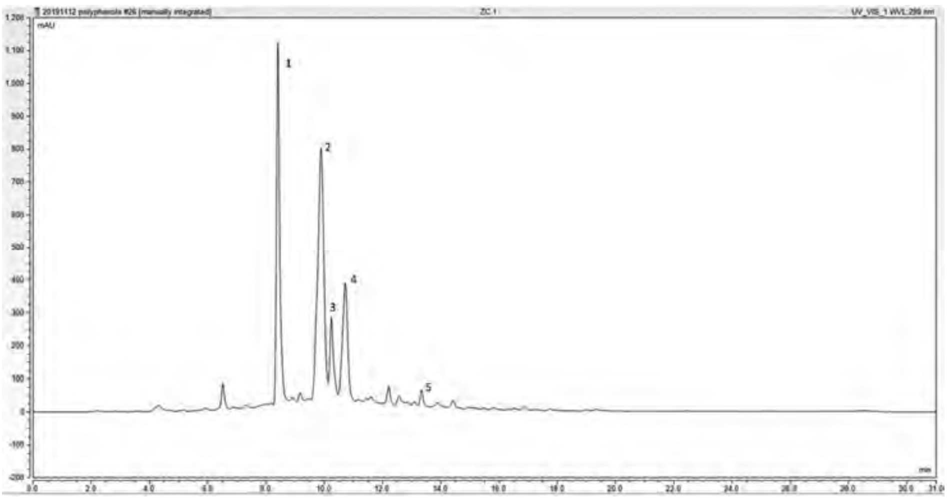

Figure 4.3: HPLC chromatogram of *zobo* control polyphenol extraction. Peak profiles of (1) unknown peak, (2) cyanidin-3-sambubioside, (3) chlorogenic acid, (4) delphinidin-3-sambubioside, and (5) ferulic acid.

There is no significant difference between the *zobo* control and *zobo* samples fortified with boiled turmeric, which shows that the addition of boiled turmeric does not increase the chlorogenic acid content of *zobo*. The addition of turmeric paste to *zobo* slightly lowered the chlorogenic acid content. We contribute this effect to natural variation in the raw material in the absence of scientific knowledge that would indicate otherwise. Previous research has found isomers of chlorogenic acid in dried *H. sabdariffa* leaves, specifically neochlorogenic acid and cryptochlorogenic acid.[56] We expect that the unknown peak in Fig. 4.3 is a stereoisomer of chlorogenic acid.

4.4 Conclusions

The present study contributes to the potential utilisation of turmeric roots in the production of street-vended *zobo* drinks. The results show that the antioxidant and nutritional quality of *zobo* (*H. sabdariffa*) drink can be improved by the way of processing (heating/boiling) and the addition of a second ingredient (i.e. turmeric) which could be easily adopted by the street vendors in Nigeria. Nowadays there is an increasing awareness of the relation between food intake and health, which has boosted the demand for health-supporting food products by consumers. Ascorbic acid, cyanidin-3-sambubioside, delphinidin-3-sambubioside, ferulic acid, and chlorogenic acid were present in turmeric-fortified *zobo*. Overall, the addition of 2% boiled turmeric in street-vended *zobo* could contribute beneficially to the Nigerian diet, due to the increased content of vitamin C and anthocyanins. Thus, by the inclusion of turmeric in *zobo* production street vendors can prepare what consumers want to be able to make healthier food choices. Presently the Nigerian Government is promoting the turmeric crop, which is relatively cheap and widely available within the country, hence making turmeric-fortified *zobo* affordable for the public.

The heat treatment applied in our study resulted in increased concentrations of vitamin C and anthocyanins. Further research is needed to determine the binding, precipitation, or aggregation effects that play a role at higher concentrations of boiled turmeric (6%) in *zobo*. We followed the traditional processing methods of the *zobo* street vendors in this study by boiling the *zobo* with turmeric. The addition of turmeric powder to *zobo* instead of turmeric paste could be another processing method that warrants follow-up research. Studies of the effect of turmeric-fortification on other street-vended drinks like soyamilk, which is rich in protein, are also recommended to determine the influence of a different food matrix.

Conflicts of interest

There are no conflicts to declare.

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References

1. Steyn NP, Mchiza Z, Hill J, Davids YD, Venter I, Hinrichsen E, et al. Nutritional contribution of street foods to the diet of people in developing countries: a systematic review. Public Health Nutrition. 2014;17(6):1363-74.

2. Izah SC, Orutugu LA, Kigigha LT. A review of the quality assessment of *zobo* drink consumed in Nigeria. ASIO Journal of Microbiology, Food Science and Biotechnology Innovations. 2015;1(1):34-44.

3. Juhari NH, Bredie WLP, Toldam-Andersen TB, Petersen MA. Characterization of Roselle calyx from different geographical origins. Food Research International. 2018;112:378-89.

4. Riaz G, Chopra R. A review on phytochemistry and therapeutic uses of *Hibiscus sabdariffa* L. Biomedicine & Pharmacotherapy. 2018;102:575-86.

5. Bechoff A, Cissé M, Fliedel G, Declemy A-L, Ayessou N, Akissoe N, et al. Relationships between anthocyanins and other compounds and sensory acceptability of Hibiscus drinks. Food chemistry. 2014;148:112-9.

6. Mohd-Esa N, Hern FS, Ismail A, Yee CL. Antioxidant activity in different parts of roselle (*Hibiscus sabdariffa* L.) extracts and potential exploitation of the seeds. Food chemistry. 2010;122(4):1055-60.

7. Jabeur I, Pereira E, Barros L, Calhelha RC, Soković M, Oliveira MBP, et al. *Hibiscus sabdariffa* L. as a source of nutrients, bioactive compounds and colouring agents. Food Research International. 2017;100:717-23.

8. Xu Y, Hu D, Bao T, Xie J, Chen W. A simple and rapid method for the preparation of pure delphinidin-3-O-sambubioside from Roselle and its antioxidant and hypoglycemic activity. Journal of Functional Foods. 2017;39:9-17.

9. Mercado-Mercado G, Blancas-Benitez FJ, Velderrain-Rodríguez GR, Montalvo-González E, González-Aguilar GA, Alvarez-Parrilla E, et al. Bioaccessibility of polyphenols released and associated to dietary fibre in calyces and decoction residues of Roselle (*Hibiscus sabdariffa* L.). Journal of functional foods. 2015;18:171-81.

10. Pérez-Ramírez IF, Castaño-Tostado E, Ramírez-de León JA, Rocha-Guzmán NE, Reynoso-Camacho R. Effect of stevia and citric acid on the stability of phenolic compounds and in vitro antioxidant and antidiabetic capacity of a roselle (*Hibiscus sabdariffa* L.) beverage. Food chemistry. 2015;172:885-92.

11. Omotayo AO. Correlates of hunger severity and food intake among rural household in Nigeria: Facing the key challenges of the 21st century. *Socioeconomica-Naučni časopis za teoriju i praksu društveno-ekonomskog razvoja*. 2018;7(14):53-76.

12. Dary O, Hurrell R. Guidelines on food fortification with micronutrients. Geneva: World Health Organization, Food and Agricultural Organization of the United Nations. 2006.

13. Nwaekpe J, Anyaegbunam H, Okoye B, Asumugha G. Promotion of turmeric for the food/pharmaceutical industry in Nigeria. Journal of Experimental Agriculture International. 2015;8(6):335-41.

14. Trifan A, Aprotosoaie AC, Miron A. Curcumin in Food. Handbook of Dietary Phytochemicals. 2019:1-44.

15. Siddiqui NA. Evaluation of thermo sensitivity of curcumin and quantification of ferulic acid and vanillin as degradation products by a validated HPTLC method. Pak J Pharm Sci. 2015;28(Suppl 1):299-305.

16. De Oliveira Silva E, Batista R. Ferulic acid and naturally occurring compounds bearing a feruloyl moiety: a review on their structures, occurrence, and potential health benefits. Comprehensive Reviews in Food Science and Food Safety. 2017;16(4):580-616.

17. Ekanem JO. Microbial, sensory and nutritional properties of laboratory prepared sorrel (*zobo*) drinks fortified with spices and sugar. Journal of Global Biosciences. 2018;7(8):5573-84.

18. Sáyago-Ayerdi SG, Arranz S, Serrano J, Goñi I. Dietary fiber content and associated antioxidant compounds in roselle flower (*Hibiscus sabdariffa* L.) beverage. J of Agricultural and Food Chemistry. 2007;55(19):7886-90.

19. Temminghoff E, Houba V. Plant analyses procedures., (Kluwer Academic Publishers: Dodrecht, The Netherlands). 2004.

20. Chen CH, Yang YH, Shen CT, Lai SM, Chang CMJ, Shieh CJ. Recovery of vitamins B from supercritical carbon dioxide-defatted rice bran powder using ultrasound water extraction. Journal of the Taiwan Institute of Chemical Engineers. 2011;42(1):124-8.

21. Hernández Y, Lobo MG, González M. Determination of vitamin C in tropical fruits: A comparative evaluation of methods. Food Chemistry. 2006;96(4):654-64.

22. Beltrán-Debón R, Alonso-Villaverde C, Aragonès G, Rodríguez-Medina I, Rull A, Micol V, et al. The aqueous extract of Hibiscus sabdariffa calices modulates the production of monocyte chemoattractant protein-1 in humans. Phytomedicine. 2010;17(3):186-91.

23. Adesokan I, Abiola O, Adigun M, Anifowose O. Analysis of quality attributes of Hibiscus sabdariffa (zobo) drinks blended with aqueous extract of ginger and garlic. African Journal of Food Science. 2013;7(7):174-7.

24. Adeniji P. Nutritional, Sensory and Microbiological Quality Assessment of fortified Zobo Drink: A Home-Prepared Traditional Nigerian Beverage. J Nutr Food Sci. 2017;7(627):2.

25. Adelekan A, Arisa N, Alamu A, Adebayo Y, Popoola G. Production and acceptability of fruits enhanced zobo drink. Food Science and Technology Letters. 2014;5(1):046-51.

26. Ezearigo O, Adeniji P, Ayoade F. Screening of natural spices for improving the microbiological, nutritional and organoleptic qualities of the Zobo drink. Journal of Applied Biosciences. 2014;76(1):6397–410.

27. Ikpeama A, Onwuka G, Nwankwo C. Nutritional composition of Tumeric (*Curcuma longa*) and its antimicrobial properties. International J Scien Eng Res. 2014;5(10):1085-9.

28. Chattopadhyay I, Biswas K, Bandyopadhyay U, Banerjee RK. Turmeric and curcumin: Biological actions and medicinal applications. Current Science. 2004;87(1):44-53.

29. Shumoy H, Lauwens S, Gabaza M, Vandevelde J, Vanhaecke F, Raes K. Traditional fermentation of tef injera: Impact on in vitro iron and zinc dialysability. Food Research International. 2017;102:93-100.

30. Cid-Ortega S, Guerrero-Beltrán J. Roselle calyces (*Hibiscus sabdariffa*), an alternative to the food and beverages industries: a review. Journal of Food Science and Technology. 2015;52(11):6859-69.

31. Karaaslan NM. A comprehensive study about *Hibiscus sabdariffa* leaves: antioxidant activity, polyphenol profile and macro-and micro-element content. Chemical Papers. 2019;73(4):791-9.

32. Voedingscentrum, Journal, *Ijzer*, https://www.voedingscentrum.nl/encyclopedie/foliumzuur.aspx;2018.

33. Voedingscentrum, Journal, *Zink*, https://www.voedingscentrum.nl/encyclopedie/ijzer.aspx;2018.

34. Cormier B, Vanderlee L, Hammond D. Use of Nutrition Information and Understanding of" Percent Daily Value" on Nutrition Facts Tables: Evaluating the Impact of a National Public Education Campaign among Youth and Young Adults in Canada. Canadian Journal of Dietetic Practice and Research: a Publication of Dietitians of Canada= Revue Canadienne de la Pratique et de la Recherche en Dietetique: une Publication des Dietetistes du Canada. 2019;80(4):200-4.

35. Bailey LB, Gregory III JF. Folate metabolism and requirements. The Journal of nutrition. 1999;129(4):779-82.

36. Simpson JL, Bailey LB, Pietrzik K, Shane B, Holzgreve W. Micronutrients and women of reproductive potential: required dietary intake and consequences of dietary deficiency or excess. Part I–folate, vitamin B12, vitamin B6. The Journal of Maternal-Fetal & Neonatal Medicine. 2010;23(12):1323-43.

37. Lawal TA, Adeleye AO. Determinants of folic acid intake during preconception and in early pregnancy by mothers in Ibadan, Nigeria. The Pan African Medical Journal. 2014;19.

38. Kumar GS, Nayaka H, Dharmesh SM, Salimath P. Free and bound phenolic antioxidants in amla (*Emblica officinalis*) and turmeric (*Curcuma longa*). Journal of food composition and analysis. 2006;19(5):446-52.

39. Obadina A, Oyewole O. Assessment of the antimicrobial potential of roselle juice (*zobo*) from different varieties of roselle calyx. Journal of food processing and preservation. 2007;31(5):607-17.

40. Fasoyiro S, Babalola S, Owosibo T. Chemical composition and sensory quality of fruit-flavoured roselle (*Hibiscus sabdariffa*) drinks. World Journal of Agricultural Sciences. 2005;1(2):161-4.

41. Onoja U, Akubor P, Gernar D, Chinmma C. Evaluation of complementary food formulated from local staples and fortified with calcium, iron and zinc. Journal of Nutrition and Food Sciences. 2014;4(6):1-6.

42. Moughan PJ. Holistic properties of foods: a changing paradigm in human nutrition. Journal of the Science of Food and Agriculture. 2020;100(14):5056-63.

43. Nasef NA, Loveday SM, Golding M, Martins RN, Shah TM, Clarke M, et al. Food matrix and co-presence of turmeric compounds influence bioavailability of curcumin in healthy humans. Food & function. 2019;10(8):4584-92.

44. Tiwari V, Shanker R, Srivastava J, Vankar PS. Change in antioxidant activity of spices-turmeric and ginger on heat treatment. Elect J Environ. 2006;5:1313-7.

45. Shen L, Jiang HH, Ji HF. Is boiled food spice curcumin still biologically active? An experimental exploration. Food & nutrition research. 2018;62.

46. Jacob RA, Sotoudeh G. Vitamin C function and status in chronic disease. Nutrition in clinical care. 2002;5(2):66-74.

CHAPTER 5

Turmeric-fortified cow and soya milk: Golden milk as a street-vended food to support consumer health

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Abstract

We studied plant-based milk from soya beans as a means to release and convey the bound antioxidants in turmeric to benefit consumer health. This was compared to cow milk as a carrier because soya milk consumption as an alternative to cow milk is increasing globally. Hence, turmeric paste was added to milk to investigate the release of turmeric antioxidants when changing the matrix (cow vs. soya), the amount of turmeric paste (0%, 2%, and 6%), and the effect of heating (with and without). Proximate, physicochemical, and mineral analyses were carried out for all samples. The total phenol content (TPC) and total antioxidant activity were measured using Folin–Ciocalteu and Quencher methods. Protein ranged from 2.0% to 4.0%, and minerals ranged from 17.8 to 85.1, 0.37 to 0.53, and 0.29 to 0.30 mg/100 mL for calcium, iron, and zinc, respectively. TPC ranged from 0.01 to 0.147 GAE (g/kg) and antioxidant activity from 7.5 to 17.7 TEAC (mmol Trolox/kg sample). Overall, turmeric added nutritional and chemical value to all the samples with and without heat treatment. However, turmeric-fortified soya milk samples showed the highest protein, iron, zinc, TPC, and antioxidant activity. This study identified a cheap, additional nutrient source for developing countries' malnourished populations by utilising soya bean milk to produce golden milk.

Keywords: sustainable meals; calcium; iron; zinc; protein; total antioxidant activity; total phenol content

5.1 Introduction

In Nigeria, turmeric (*Curcuma longa* L.) is widely available. An increase in turmeric production and processing could improve the country's economic development and nutritional status [1] and is, therefore, stimulated by the government. Turmeric is considered a health-supporting food ingredient, related primarily to the lipophilic bioactive compound curcumin with antioxidant properties and anti-inflammatory properties.[2] Familiar street-vended drinks (soya milk and the hibiscus–a water-based drink called *zobo*) have been fortified with turmeric; we previously reported the consumers' overall acceptability of these novel turmeric-fortified drinks.[3] The antioxidant and nutritional quality of street-vended *zobo* (*Hibiscus sabdariffa*) drink fortified with turmeric has also been reported.[4]

Turmeric milk, called "*haldi doodh*" in India, is an example of a traditional drink often consumed to treat a sore throat and as a home therapy for fever.[5] Various ailments such as duodenal ulcer, asthma, malaria, cough, and cold can also be addressed with boiled turmeric milk.[6] Moreover, consumers' increasing preference for natural and healthy foods has contributed to the popularity of turmeric milk, which is now known as "golden milk" globally. Since golden milk is widely consumed and its consumption is gaining popularity globally, the claims of its antioxidant and nutritional qualities must be scientifically validated.

Soya milk is a watery extract of soya beans (*Glycine max* L.). In the northern part of Nigeria, soya beans are grown and play a vital role in the dietary pattern of the population for their nutritional value. Soya bean is the plant with the highest percentage of GMOs grown worldwide. Genetically modified soya beans account for 82% of the overall crop. Soya is grown all over the world and is a nutrient-dense food that is also a good source of protein, providing vital dietary amino acids.[7] According to Mazumder and Begum[8], soya milk contains significant amounts of essential and branched-chain amino acids. The differences in amino acids between cow and soya milk are further reported in their study. The non-availability and high cost of cow milk in developing countries have led to the promotion of milk from plants, especially soya milk.[9] The commercial production of soya milk, sold as a street-vended drink in these countries, especially Nigeria, helps mitigate the vendors' poverty.[10] Globally, the absence of gluten, lactose, and cholesterol has made soya milk a good alternative for those with lactose intolerance or galactosemia and vegetarians.[11] Hence, soya milk has also gained much popularity as a vegan and healthy drink in developed countries where lactose intolerance among the elderly and cow milk allergy among infants and children are increasing.[12,13] Additionally, soya milk is similar to cow milk in appearance, and its consistency makes it a good milk analogue.[14]

Cow milk is a source of energy, protein, and fat, and a high milk intake contributes to increased height, stronger bones, and better dental health.[15] In addition, cow milk contains all B vitamins and has antioxidant properties. Ascorbic acid is the primary water-soluble antioxidant in milk, and vitamins A and E are the primary lipid-soluble antioxidants.[16] Several studies have been carried out on both cow and soya milk's phenolic and antioxidant activity. Temperature, pH, protein type, and concentration have been reported as fundamental parameters that can affect protein–phenolic interactions.[13,17–19]

In recent years, milk products have been reported as a distinctive carrier, suitable to distribute nutrients and phytochemicals for health benefits in our nutritional system.[20,21] Investigating the use of soya milk in developing many native dairy-based foods that have demand globally has been recommended.[12,22–24] Cow and soya milk have been fortified with herbs, spices, and plant extracts.[11,20,25,26] Such fortification with herbs and spices or their extracts uses such fortified milk products as carriers for health-supporting compounds.

This study investigated whether turmeric-fortified soya milk is a suitable drink to improve the diet of the low-income population of urbanized areas in developing countries. We explored the differences in the interaction between turmeric components and cow milk vs. soya proteins. Hence, the effect of changing the matrix (cow vs. soya), the amount of turmeric paste (0%, 2%, and 6%), and the effect of heating (with and without) on the nutritional and chemical properties of the so-called golden milk were assessed.

5.2 Materials and Methods

Materials

Whole, skimmed, and soya milk produced in the Netherlands were purchased at a local supermarket (Wageningen, The Netherlands). Turmeric rhizomes were purchased from the Omuooke-Ekiti (7°45'29.99" N, 5°43'20.17" E) market located in Ekiti State, Nigeria. All the samples were taken to the laboratory of the Food Quality and Design Group of Wageningen University and Research (Wageningen, The Netherlands) for preparation and analysis. All chemicals used were of analytical quality.

Preparation of turmeric-fortified milk

Turmeric-fortified milk was prepared by adding two fresh turmeric paste concentrations, namely 2% and 6% turmeric in whole, skimmed, and soya milk. Milk without fresh turmeric paste (0%) was made as the control sample for all the milk types. All samples were prepared with and without heat treatment. Fresh turmeric paste was produced at turmeric:tap water ratio of 1:2 on a weight basis by mixing with a blender (Waring Heavy-Duty Laboratory Blender, Wertheim, Germany) at high speed for 10 min until a fine paste was formed (Figure 5.1a).

Whole, skimmed, and soya milk were purchased in amounts of at least six litres at once for each milk type and mixed in a large bucket to minimize biological variation. Next, one litre of turmeric milk was prepared for each treatment (Figure 5.1b). The samples received a heat treatment by gently boiling them for 2 min on an electric cooker (Tristar KP-6245, Mechernich, Germany) to prevent the milk from curdling. Due to the nonhomogeneous distribution of particles in the turmeric-fortified milk, as shown in Figure 5.1b for 6% turmeric-fortified whole milk, all samples were freeze-dried using a vacuum freeze dryer (Zirbus Technology GmbH, Bad Grund, Germany) for 168 h at a minimum of -20 °C (Figure 5.1c). After freeze-drying, the samples were milled in a planetary ball miller (Retsch MM 400, Haan, Germany) to obtain a homogeneous powder (Figure 5.1d) for all samples (Figure 5.1e). Figure 5.2 schematically shows the preparation of turmeric-fortified whole, skimmed, and soya milk samples as well as the laboratory analyses.

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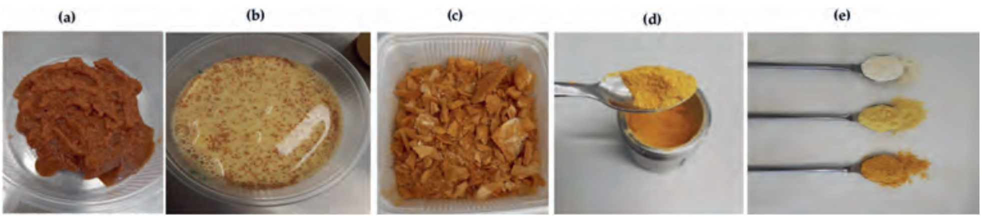

Figure 5.1: The preparation of homogeneous turmeric-fortified milk samples: (a) fresh turmeric paste, (b) 6% turmeric-fortified whole milk, (c) freeze-dried 6% turmeric-fortified whole milk, and (d) milled freeze-dried 6% turmeric-fortified whole milk (e) from up to down, 0%, 2%, and 6% milled freeze-dried turmeric-fortified whole milk samples.

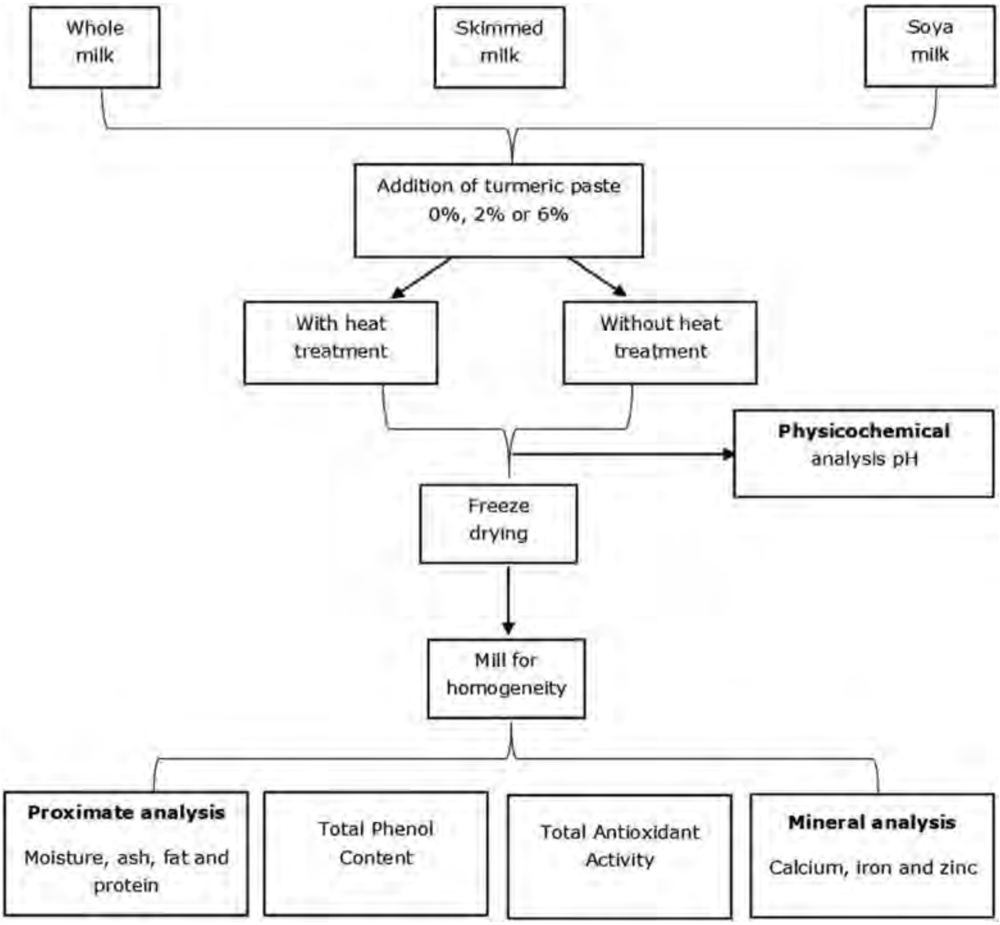

Figure 5.2: Schematic diagram of the preparation of the turmeric-fortified cow and soya milk samples with the subsequent laboratory analyses.

Measurement of pH

After preparing the milk samples, the pH was measured in duplicate, using a pH meter (VWR pH 1100L, Radnor, PA, USA). The pH meter was calibrated using technical buffer solutions of pH 4 and pH 7 (VWR, Radnor, PA, USA) before measurement.

Proximate analysis

Moisture and ash content

The moisture content was determined following the method described by Ekanem.[27] The ash content was determined by heating the freeze-dried samples in an ash oven (Carbolite Furnaces CSF 1100, Aartselaar, Belgium) at 550 °C for 8 h, after the method of Ekanem[27] Afterward the ash content was calculated by using the following equation:

$$Ash\ content = \frac{Weight\ of\ the\ sample\ after\ ashing}{Weight\ of\ the\ sample\ transferred\ before\ ashing} \times 100\%$$

Fat content

The fat content was determined by the method of Manirakiza et al.[28], with the following modifications: one gram of freeze-dried sample was weighed on an analytical balance (Mettler-Toledo XA105, Giessen, Germany) with an accuracy of 0.1 mg in extraction thimbles with 200 mL petroleum ether (Merck 1.01774.2500, Burlington, MA, USA) in flat-bottom flasks. The flat-bottom flask was connected to the extractor, put on a heating block (Labotech blocks, Gottingen, Germany), and boiled for at least 3 h. After the extraction, the petroleum ether in the flat-bottom flask was left to cool for 1 h and evaporated using a rotary evaporator (Büchi Rotavapor R-300, Essen, Germany) under a vacuum. The flat-bottom flask was then left overnight to get rid of the last bit of petroleum ether and then weighed on the same analytical balance used at the beginning of the experiment.

Protein content

Protein content was analysed in duplicate using a LECO CN 628 Dumas analyser, Bonn, Germany. Powdered treatment samples and blank samples with cellulose (Sigma Aldrich 310697, St. Louis, MO, USA) were weighed in tin cups (Interscience, Ottignies- Louvain-la-Neuve, Belgium) and put in a sample tray with 40 positions covered with aluminium foil to protect the tin cups. The samples were then oxidised in the Dumas metal column filled with chemicals at high temperature with water filters in a separation column on which nitrogen was separated and calculated into protein content. The conversion factor used to calculate the protein content was 6.25 for cow milk protein and 5.8 for soya milk protein.[29]

Mineral content

The mineral content was measured by digesting the samples in a microwave oven (MARS 6 iWave, CEM Corporation, Mattews, NC, the United States of America with sulfuric acid, hydrogen peroxide, and hydrochloric acid.[30] This solution was atomized in argon plasma, and due to the high temperature, the sample dried further and was ashed, atomized, and ionized. The minerals were detected using an ICP-MS (Agilent 7800 ICP MS, Matthews, NC, USA), and the signal intensity of the mineral was divided by the charge of the minerals.[31] The mineral content was quantified by means of a calibration line based on the ratio between the signal of the element and the signal of the associated standard.

Total phenol content

The total phenol content was determined by the Folin–Ciocalteu method,[32] with the following modifications: the extraction of the phenolic compounds in turmeric-fortified milk samples was done by weighing 0.5 g of freeze-dried material in a 15 mL disposable tube. After that, 4 mL preheated CH_3OH 100% (Merck, Burlington, MA, USA) incubated at 75 °C for 60 min (Julabo SW-20C, Seelbach, Germany) was added to the disposable tube and further incubated for 20 min at 75 °C. The tubes were mixed every 5 min using a vortex (Scientific Industries Vortex Genie 1, Bohemia, New York, NY, USA). After 20 min, the tubes were centrifuged (Eppendorf AG Centrifuge 5430 R, Hamburg, Germany) at 2500 rpm (699 g) for 10 min at 20 °C. The supernatant was collected, and the pellet was re-extracted two times, with 2 mL 70% CH_3OH at 20 min incubation time. The supernatants were combined and stored in the freezer at 20 °C until further analysis. The supernatant (1 mL), 5 mL of demi water, 1 mL Folin–Ciocalteu reagents (Merck 109001.0500, Burlington, MA, USA) and 1 mL of saturated Na2CO3 (Merck 6329, USA) were added into a 25 mL volumetric flask. The volume was adjusted to 25 mL with demi water and mixed well by hand. The absorbance was measured at 750 nm using a spectrophotometer (Cary 50 Bio UV–Vis spectrophotometer, Walnut Creek, CA, USA) after 15 min. The gallic acid equivalent (GAE) was calculated using gallic acid (Sigma Aldrich 27654, St. Louis, MO, USA) as a reference standard. The concentration range of the gallic acid standard curve was 0.02–0.5 mg/mL. The standard curve was linear, and the equation of the line used was $y = 4.3008x + 0.0219$, with $R^2 = 0.9998$.

Total antioxidant activity

The total antioxidant activity was measured by the Quencher procedure [33] with the following modifications: a stock solution was made with 1,1-diphenyl-2-picryl-hydrazyl (DPPH; Sigma Aldrich, St. Louis, MO, USA) by preparing 10 mg DPPH/mL 100% pure ethanol (Merck, Burlington, MA, USA). The stock solution was then diluted to 5 mg/mL in Milli-Q water (VWR, Radnor, PA, USA) and subsequently diluted 125× by adding 200 µL DPPH stock to

25 mL 50% ethanol. This solution was prepared 24 h in advance in the dark to activate it. The calibration curve was prepared with 6 hydroxy 2,5,7,8 tetramethylchroman 2-carboxylic acid (Trolox 23881-3; Sigma Aldrich, St. Louis, MO, USA). A stock solution of Trolox in 100% ethanol was prepared by adding 20 mg of Trolox to 1 mL of 100% ethanol. This stock solution was diluted to 5.33×, 8×, 16×, and 40× in 100% ethanol to get four points calibration curve of 3.75, 2.5, 1.25, and 0.50 mg/mL. In addition, a blank of 100% ethanol were prepared in triplicates and the absorbance of the blank (average value of its triplicates) was taken as the initial concentration in the test (0.00 mmol). All freeze-dried milk samples were diluted with cellulose by combining 100 mg of cellulose with 100 mg of milk in an aluminium dish with a spatula (1:1 ratio). A 1:1 ratio was used for 0% turmeric in milk samples. The turmeric-fortified milk samples required a 2:1 ratio due to their high yellow pigmentation. Next, 10, 20, and 40 mg samples in 5 mL Eppendorf tubes were prepared, and 5 mL DPPH was added to each milk type and Trolox sample. After incubation in the Heidolph shaker (Multi Reax Vortexer, Schwabach, Germany), the samples were centrifuged for 5 min at 9000 rcf at room temperature. The absorbance of the supernatant was measured at 525 nm in the spectrophotometer (Cary 50 Bio UV–Vis spectrophotometer, Walnut Creek, CA, USA).

Data analysis

All variables are reported as means ± standard deviation (SD) with a minimum of two replicates. A Heatmapper webserver was used to visualize all samples' proximate and physicochemical composition.[34] The difference between samples with and without heat treatment was tested by two-way analysis of variance (ANOVA) followed by the post hoc Tukey test and One-Way ANOVA to evaluate the relationship between variables and milk type using IBM SPSS Statistics 25. The differences in means were considered significantly different at $p < 0.05$.

5

5.3 Results and discussion

Proximate and physicochemical composition

Before and after heat treatment, the moisture content for control samples ranged from 88.6–89.7%, 89.8–90.7%, and 88.4–89.5% for whole milk, skimmed milk, and soya milk, respectively. The moisture content of the turmeric-fortified whole milk, skimmed milk, and soya milk samples ranged from 86.7% to 88.5%, 90.4% to 91.3%, and 87.9% to 89.0%, respectively. For all the milk types, 6% turmeric-fortified samples had the lowest moisture content before and after heat treatments. However, the mean values of moisture contents of 2% turmeric-fortified samples were significantly lower than that of the control samples (p <

0.05). The same trends were observed between the 6% and 2% turmeric-fortified whole and soya milk. In addition, 6% heat-treated turmeric-fortified skimmed milk showed no significant difference from both 0% and 2% turmeric-fortified ones ($p < 0.05$). These results were similar to those of previous studies.[35,36]

The ash content for control samples ranged from 0.7% to 0.8%, 1.0% to 1.1%, and 0.4% to 0.5% for whole milk, skimmed milk, and soya milk, respectively. The ash content of the turmeric-fortified skimmed milk ranged from 1.1% to 1.2%. The turmeric-fortified whole and soya milk ash contents were within the range of the control sample. Before heat treatment, the ash content of the turmeric-fortified samples differed significantly from the control samples for all the milk types. However, no significant differences were observed between the 2% and 6% turmeric-fortified samples ($p < 0.05$). After heat treatment, there were no significant differences observed among the control and fortified samples ($p < 0.05$). The fat content for both control and turmeric-fortified milk samples ranged from 0.1% to 1.6% with significant differences observed among all treatments for the turmeric-fortified whole and soya milk samples ($p < 0.05$). The pH of all samples was relatively stable and independent of turmeric addition before and after heat treatment.

The protein content for control samples ranged from 2.3% to 2.4%, 3.4% to 3.6%, and 3.5% to 4.0% for whole milk, skimmed milk, and soya milk, respectively. The protein content of the turmeric-fortified whole milk, skimmed milk, and soya milk samples ranged from 1.7% to 2.1%, 3.1% to 3.8%, and 3.5% to3.9%, respectively. Natural crude polyphenols from plants such as grape (*Vitis vinifera*) and tea (*Camellia sinensis*) and cranberry (*Vaccinium oxycoccos*) extracts have been reported to have strong bindings with milk proteins.[37] Thus, the reduction in the protein contents for the milk samples fortified with turmeric could be because of the binding by polyphenols originating from the turmeric, though, the reduction showed no significant difference at ($p < 0.05$). Overall, the results in this study were in line with the proximate composition of herbal *sandesh*, an Indian coagulated milk product with turmeric, spinach (*Spinacia oleracea*), curry leaf (*Murraya koenigii*), coriander (*Coriandrum sativum*), and aonla (*Emblica officinalis*).[38] The proximate and physicochemical compositions visualized with the heatmap (Figure 5.3) show that the samples fall into three clusters according to milk type.

Mineral content

Zinc and iron are the most predominant deficient micronutrients in human diets globally.[39] Calcium is also an important mineral found in milk. Consumers may be at risk of calcium deficiencies if they substitute non-fortified and non-supplemented plant drinks for cow's milk.[40] Thus, the minerals measured in this present study were calcium, iron, and zinc. The calcium, iron, and zinc contents of turmeric-fortified whole and soya milk samples after heat treatment ranged from 17.8 to 85.1, 0.37 to 0.53, and 0.29 to 0.30 mg/100 mL, respectively. Calcium content of 120 mg/100 mL was declared on the packaging of both the whole and soya milk used in this study. This value was high compared to the calcium content of our control samples, with soya milk showing the lowest values.

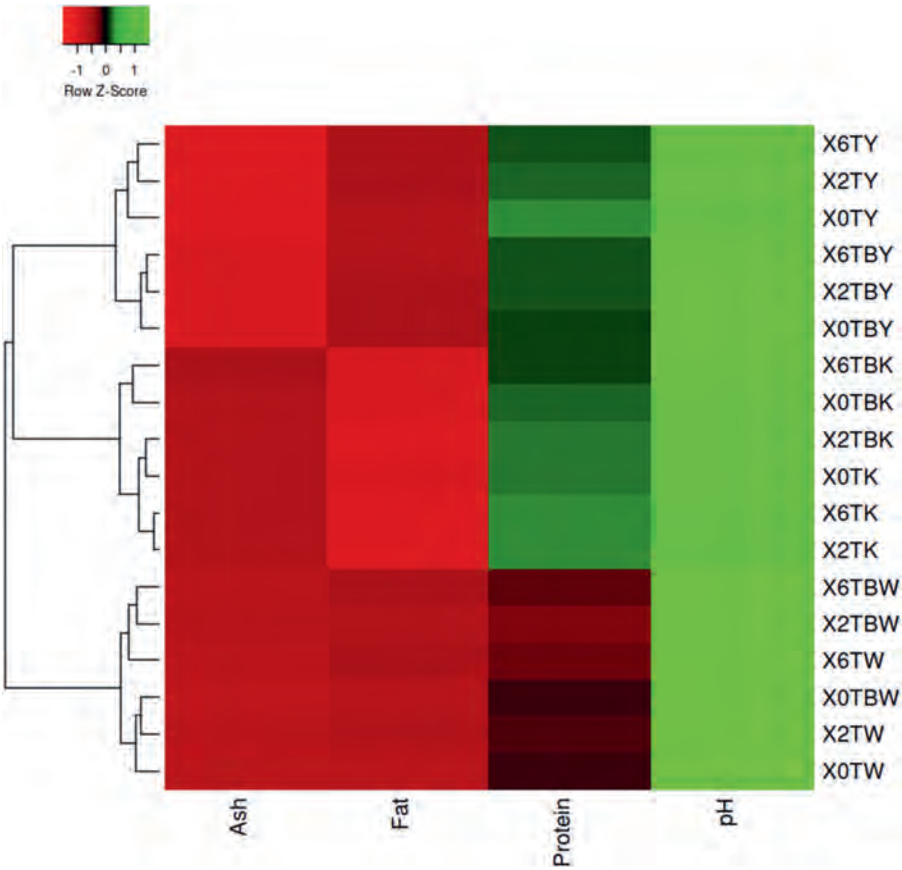

Figure 5.3: Heatmap of the pH, ash, fat, and protein content of three types of turmeric-fortified milk. Mean values refer to colours from minimum (displayed in red) to maximum (represented with green). Key: TW, TK, and TY represent turmeric-fortified whole milk, skimmed milk, and soya milk respectively. TBW, TBK, and TBY represent boiled turmeric-fortified whole milk, skimmed milk, and soya milk, respectively. X means sample and the number 0, 2, or 6 represents the percentage of turmeric in each sample.

Soya milk does not naturally contain such high levels of calcium as declared on the packaging. However, soya milk is generally fortified with calcium to create a comparable composition to cow milk to make it a suitable milk alternative.[41] The higher the storage temperature, the higher the sedimentation in milk beverages.[42] The soya milk in this research was stored at room temperature, which may have caused high sedimentation in the package. We suspect that this could have influenced the mineral composition of the control soya milk samples.

Nevertheless, the amount of calcium, as well as iron and zinc in all soya milk samples in this study, agrees with,[43] who reported values of 18.5, 0.5, and 0.3 mg/100 mL for calcium, iron, and zinc, respectively, for freshly prepared soya milk. Both iron and zinc increase with the increasing concentration of turmeric. The values of these minerals in samples with 6% turmeric agreed with previous research.[43] The value was higher than commonly reported in the literature.[8,44] The differences in the absorption of iron result not only from individual variability but also from the type of food in which it is supplied. The iron of milk origin is absorbed much better than the iron from turmeric. Furthermore, the ash content, which represents the total minerals in food,[45] did not increase with the addition of turmeric in the turmeric-fortified soya milk samples. Thus, turmeric only seems to prevent loss of minerals due to sedimentation in soya milk during storage.

Total phenol content

Milk type, turmeric paste concentration, and heat treatment (Table 5.1) had a significant effect ($p < 0.05$) on the total phenol content (TPC) of golden milk. The TPC value of control whole milk was lower than the values reported previously.[32,46] It should be noted though that the milk used in this study was commercially available, UHT-sterilized milk. The severe thermal sterilization treatment might have triggered reactions that affected the phenolic composition by releasing the phenolic compounds from their bonded forms, causing subsequent degradation, hydrolysis, and transformations.[47] Moreover, even though commercial milk samples were used by others, the freeze-drying process to obtain homogenous and solid samples could have lowered the TPC in our study.[46]

Turmeric-fortified soya milk showed a higher phenol content than turmeric-fortified cow milk, which agrees with previous research.[48] Without turmeric, the TPC of soya milk was 0.09 GAE/kg sample.

Table 5.1: Total phenolic compounds, expressed in milligrams of GAE per kg of whole milk, skimmed milk, and soya milk

		GAE (g/kg sample)	
	Sample	Unboiled	Boiled
Whole milk	0% Turmeric	0.01 ± 0.5 [a,1]	0.03 ± 0.2[a,1]
	2% Turmeric	0.03 ± 0.2 [a,2]	0.04 ± 0.2[a,2]
	6% Turmeric	0.05 ± 0.4 [a,3]	0.05 ± 1.6[a,2]
Skimmed milk	0% Turmeric	0.01 ± 0.1 [a,1]	0.02 ± 0.6[a,1]
	2% Turmeric	0.04 ± 0.9 [a,2]	0.05 ± 2.2[a,1]
	6% Turmeric	0.08± 1.5 [b,3]	0.08 ± 1.2[a,1]
Soya milk	0% Turmeric	0.09 ± 0.2[b,1]	0.10 ± 1.7[b,1]
	2% Turmeric	0.10 ± 1.1[b,1]	0.11 ± 0.7[b,2]
	6% Turmeric	0.14 ± 1.6[c,2]	0.13 ± 2.2[b,3]

Values are the means of three independent measurements. [a-c] Different letters indicate a significant difference between the three types of turmeric-fortified milk with the same turmeric percentage and heat treatment. [1-3] Different numbers indicate a significant difference for a certain turmeric percentage within the same milk type and heat treatment ($p < 0.05$).

The TPC of soya milk was higher than that of whole milk and skimmed milk. Moreover, 2% turmeric gave 0.10 GAE/kg and 6% turmeric, 0.14 GAE/kg. Soya beans are a good source of many nutrients, including polyphenols. Values of TPC in soya beans depend on variety and practices to produce soya milk, causing variations between products and brands.[49] Adding turmeric generally showed a significant increase in the TPC for the three milk types. Adding a higher amount of turmeric (6%) is beneficial from a nutrition perspective.[50] Even though the TPC decreased after heat treatment when 6% turmeric was added to all the milk samples, boiling milk protects the milk from spoilage microorganisms. Considering the challenges of improving hygiene in developing countries, boiling milk at low–medium heat is strongly recommended.[51] In general, however, the boiling (which would be good from a food safety perspective) does not annihilate the increase of TPC due to the 2% addition of turmeric. Besides, whilst 0% turmeric in boiled skimmed milk showed the lowest TPC, the addition of turmeric complemented this deficit with 6% turmeric in boiled skimmed milk, which roughly showed a 25% increase.

Antioxidant activity

The addition of turmeric showed a significant increase in antioxidant activity, and when more turmeric was added to whole milk, the antioxidant activity increased (Table 5.2). Heat treatment of whole milk showed a significant decrease for the samples with 0% and 2% turmeric but a slight increase for the sample with 6% turmeric. Overall, the antioxidant activity increased with the addition of turmeric. Whole milk before treatment showed a similar value of the antioxidant activity as skimmed milk. These values differed from the value reported in the literature.[52] The low-fat content of our whole milk sample may be responsible for the discrepancy as the antioxidant activity has been linked to the chemical content of milk from different species, particularly in cows.[53] The difference could also be due to different processing methods applied before measurement. According to Khan et al.,[16] boiling did not affect the antioxidant activity of cow milk, which is in line with the whole milk samples in this research.

Table 5.2: Antioxidant activities of turmeric-fortified whole milk, skimmed milk, and soya milk before and after heat treatment expressed in Trolox equivalent antioxidant capacity (TEAC)

		TEAC (mmol Trolox/kg sample)	
	Sample	Unboiled	Boiled
	0% Turmeric	$0.5 \pm 0.1^{a,1}$	$0.1 \pm 0.1^{a,1}$
Whole milk	2% Turmeric	$3.8 \pm 0.4^{ab,2}$	$1.4 \pm 0.1^{a,2}$
	6% Turmeric	$5.1 \pm 1.1^{a,2}$	$5.3 \pm 0.1^{a,3}$
	0% Turmeric	$0.5 \pm 0.4^{a,1}$	0.4 ± 0.2^{b1}
Skimmed milk	2% Turmeric	$2.9 \pm 0.3^{a,2}$	$2.6 \pm 0.4^{a,2}$
	6% Turmeric	$5.6 \pm 0.5^{a,3}$	$5.6 \pm 0.1^{a,3}$
	0% Turmeric	$3.4 \pm 0.1^{b,1}$	$7.5 \pm 0.3^{a,1}$
Soymilk	2% Turmeric	$4.6 \pm 0.2^{b,1}$	$11.6 \pm 0.7^{b,2}$
	6% Turmeric	$4.5 \pm 0.8^{a,1}$	$17.7 \pm 0.9^{b,3}$

Different letters indicate a significant difference in milk type within the same turmeric percentage and heat treatment. Different numbers indicate a significant difference in turmeric percentage within the same milk type and heat treatment ($p < 0.05$).

The antioxidant activity of skimmed milk without turmeric was low, and the addition of turmeric increased the antioxidant activity significantly. Heat treatment did not significantly affect the antioxidant activity of the skimmed milk samples. In line with previous research,[54] neither the differences in fat content nor heat treatment caused significant differences in the antioxidant values. Raw milk, which is commonly used in studies to measure antioxidant activity, has different properties than the commercial UHT milk used in the present research.[55]

The initial antioxidant activity of soya milk without turmeric was much higher than that of whole milk and skimmed milk. The addition of 2% and 6% turmeric showed a large increase in antioxidant activity. Heat treatment also significantly increased the antioxidant activity. The significantly higher antioxidant activity of soya milk compared to that of cow milk agrees with previous research.[56] Soya bean is known to have a high antioxidant activity due to polyphenolic antioxidants, such as isoflavones. Overall, the addition of turmeric to both cow and soya milk formed a nutritionally better product.[57] Furthermore, in this research, soya milk showed the highest antioxidant activity, regardless of heat treatment.

5.4 Conclusions

Consumer preferences for healthy foods have increased the popularity of golden milk across the globe. To the best of our knowledge, this is the first scientific literature to investigate the antioxidant and nutritional compositions of this widely consumed functional drink. This study also provides a basis for developing novel turmeric-fortified soya milk, which is nutritionally equivalent to the popular golden milk (turmeric-fortified cow milk). Turmeric added nutritional and chemical values to all three milk varieties without heat treatment. The effect of heat treatment on turmeric-fortified milk significantly impacted the TPC of 0% and 6% turmeric in whole milk. The phenolic compounds, antioxidant activity, protein, and iron increased with 2% and 6% turmeric in soya milk. Thus, soya milk appears to be the best matrix to deliver the antioxidant benefits of turmeric to the cow-milk-allergic populace and the low-income population of urbanized areas in developing countries. Overall, this research serves as a starting point to validate the claims of golden milk's benefits. The present work standardized the levels of turmeric concentration and also studied the effect of heat treatment using soya milk as an alternative. However, further research is recommended to study the bioavailability of minerals and bioactive compounds after the intake of turmeric-fortified milk.

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References

1. Nwaekpe J, Anyaegbunam H, Okoye B, Asumugha G. Promotion of turmeric for the food/pharmaceutical industry in Nigeria. Journal of Experimental Agriculture International. 2015;8(6):335-41.

2. Hewlings SJ, Kalman DS. Curcumin: a review of its effects on human health. Foods. 2017;6(10):92.

3. Idowu-Adebayo F, Fogliano V, Oluwamukomi MO, Oladimeji S, Linnemann AR. Food neophobia among Nigerian consumers: A study on attitudes towards novel turmeric-fortified drinks. Journal of the Science of Food and Agriculture. 2021;101:3246-56.

4. Idowu-Adebayo F, Toohey MJ, Fogliano V, Linnemann AR. Enriching street-vended *zobo* (*Hibiscus sabdariffa*) drink with turmeric (*Curcuma longa*) to increase its health-supporting properties. Food & Function. 2021;12:761-70.

5. Araujo C, Leon L. Biological activities of *Curcuma longa* L. Memórias do Instituto Oswaldo Cruz. 2001;96(5):723-8.

6. Velayudhan K, Dikshit N, Nizar MA. Ethnobotany of turmeric (*Curcuma longa* L.). Indian Journal of Traditional Knowledge. 2012;11(4):607-14.

7. Čosić A, Karić A, Šabanović K, Šutković J, Yildirim A. Determination of GMO soy products in processed food from Bosnian market. Bioengineering Studies. 2020;1(1):14-20.

8. Mazumder MAR, Begum AA. Soy milk as source of nutrient for malnourished population of developing country: A review. International Journal of Advanced Scientific and Technical Research. 2016;5(6):192-203.

9. Ezeigbo O, Ekaiko M, Kalu T, Nwodu J. Quality Assessment of Soymilk Sold in Aba, Southeastern Nigeria. International Journal of Epidemiology & Infection 2014;2(4):88-91.

10. Osuntogun B, Aboaba O. Microbiological and physico-chemical evaluation of some non-alcoholic beverages. Pakistan Journal of nutrition. 2004;3(3):188-92.

11. Sęczyk Ł, Świeca M, Gawlik-Dziki U. Soymilk enriched with green coffee phenolics–Antioxidant and nutritional properties in the light of phenolics-food matrix interactions. Food Chemistry. 2017;223:1-7.

12. Paul AA, Kumar S, Kumar V, Sharma R. Milk Analogue: Plant based alternatives to conventional milk, production, potential and health concerns. Critical reviews in food science and nutrition. 2020;60(18):3005-23.

13. Silván JM, Amigo-Benavent M, del Castillo MD. Antioxidant Properties of Soy-Based Drinks and Effects of Processing. Processing and impact on antioxidants in beverages: Elsevier; 2014. p. 225-32.

14. Rizzo G, Baroni L. Soy foods and their role in vegetarian diets. Nutrients. 2018;10(1):43.

15. Vanderhout SM, Aglipay M, Torabi N, Jüni P, da Costa BR, Birken CS, et al. Whole milk compared with reduced-fat milk and childhood overweight: a systematic review and meta-analysis. The American journal of clinical nutrition. 2020;111(2):266-79.

16. Khan IT, Nadeem M, Imran M, Ayaz M, Ajmal M, Ellahi MY, et al. Antioxidant capacity and fatty acids characterization of heat treated cow and buffalo milk. Lipids in health and disease. 2017;16(1):1-10.

17. Jung S, Murphy PA, Sala I. Isoflavone profiles of soymilk as affected by high-pressure treatments of soymilk and soybeans. Food Chemistry. 2008;111(3):592-8.

18. Ren C, Xiong W, Peng D, He Y, Zhou P, Li J, et al. Effects of thermal sterilization on soy protein isolate/polyphenol complexes: Aspects of structure, in vitro digestibility and antioxidant activity. Food research international. 2018;112:284-90.

19. Ozdal T, Capanoglu E, Altay F. A review on protein–phenolic interactions and associated changes. Food Research International. 2013;51(2):954-70.

20. El-Sayed SM, Youssef AM. Potential application of herbs and spices and their effects in functional dairy products. Heliyon. 2019;5(6):e01989.

21. Bhattacharyya S, Chakraborty C, Moitra S, Bandyopadhyay K. Potential application of milk and milk products as carrier for herbs and spices: a Review. Int J Eng Res Sci Technol. 2017;6:113-24.

22. Yamamoto N, Shoji M, Hoshigami H, Watanabe K, Takatsuzu T, Yasuda S, et al. Antioxidant capacity of soymilk yogurt and exopolysaccharides produced by lactic acid bacteria. Bioscience of microbiota, food and health. 2019:18-017.

23. Pratap D, Singh R, Ravichandran C, Ojha A, Upadhyay A, Kaur BP, et al. Evaluation of physicochemical, antioxidant, and sensory characteristics of khoa prepared from blends of soy and standardized milk. Journal of Food Processing and Preservation. 2019;43(11):e14215.

24. Fardet A, Rock E. In vitro and in vivo antioxidant potential of milks, yoghurts, fermented milks and cheeses: a narrative review of evidence. Nutrition Research Reviews. 2018;31(1):52-70.

25. Park H, Lee M, Kim KT, Park E, Paik HD. Antioxidant and antigenotoxic effect of dairy products supplemented with red ginseng extract. Journal of dairy science. 2018;101(10):8702-10.

26. Ye J, Fan F, Xu X, Liang Y. Interactions of black and green tea polyphenols with whole milk. Food Research International. 2013;53(1):449-55.

27. Ekanem JO. Microbial, sensory and nutritional properties of laboratory prepared sorrel (*zobo*) drinks fortified with spices and sugar. Journal of Global Biosciences. 2018;7(8):5573-84.

28. Manirakiza P, Covaci A, Schepens P. Comparative study on total lipid determination using Soxhlet, Roese-Gottlieb, Bligh & Dyer, and modified Bligh & Dyer extraction methods. Journal of food composition and analysis. 2001;14(1):93-100.

29. Sáyago-Ayerdi SG, Arranz S, Serrano J, Goñi I. Dietary fiber content and associated antioxidant compounds in roselle flower (*Hibiscus sabdariffa* L.) beverage. J of Agricultural and Food Chemistry. 2007;55(19):7886-90.

30. Meyer S, Markova M, Pohl G, Marschall TA, Pivovarova O, Pfeiffer AFH, et al. Development, validation and application of an ICP-MS/MS method to quantify minerals and (ultra-)trace elements in human serum. Journal of Trace Elements in Medicine and Biology. 2018;49:157-63.

31. Temminghoff E, Houba V. Plant analyses procedures.,(Kluwer Academic Publishers: Dodrecht, The Netherlands). 2004.

32. Vázquez CV, Rojas MGV, Ramírez CA, Chávez-Servín JL, García-Gasca T, Martínez RAF, et al. Total phenolic compounds in milk from different species. Design of an extraction technique for quantification using the Folin–Ciocalteu method. Food Chemistry. 2015;176:480-6.

33. Serpen A, Gökmen V, Fogliano V. Solvent effects on total antioxidant capacity of foods measured by direct Quencher procedure. Journal of Food Composition and Analysis. 2012;26(1-2):52-7.

34. Benabderrahim MA, Yahia Y, Bettaieb I, Elfalleh W, Nagaz K. Antioxidant activity and phenolic profile of a collection of medicinal plants from Tunisian arid and Saharan regions. Industrial Crops and Products. 2019;138:111427.

35. Hajirostamloo B, Mahastie P. Comparison of nutritional and chemical parameters of soymilk and cow milk. World Academy of Science, Engineering and Technology. 2009;57(9):436-8.

36. Woodside JV, Brennan S, Cantwell M. Are Soy-Milk Products Viable Alternatives to Cow's Milk? Beverage Impacts on Health and Nutrition: Springer; 2016. p. 151-62.

37. Han J, Chang Y, Britten M, St-Gelais D, Champagne CP, Fustier P, et al. Interactions of phenolic compounds with milk proteins. European Food Research and Technology. 2019;245(9):1881-8.

38. Bandyopadhyay M, Chakraborty R, Raychaudhuri U. Incorporation of herbs into sandesh, an Indian sweet dairy product, as a source of natural antioxidants. International Journal of Dairy Technology. 2007;60(3):228-33.

39. Kihara J, Bolo P, Kinyua M, Rurinda J, Piikki K. Micronutrient deficiencies in African soils and the human nutritional nexus: opportunities with staple crops. Environmental Geochemistry and Health. 2020;42(9):3015-33.

40. Scholz-Ahrens KE, Ahrens F, Barth CA. Nutritional and health attributes of milk and milk imitations. European journal of nutrition. 2020;59(1):19-34.

41. Nieves JW. Osteoporosis: the role of micronutrients. The American journal of clinical nutrition. 2005;81(5):1232S-9S.

42. Koffi E, Shewfelt R, Wicker L. Storage stability and sensory analysis of uht-processed whey-banana beverages. Journal of food quality. 2005;28(4):386-401.

43. Nti CA, Plahar WA, Annan NT. Development and quality characteristics of shelf-stable soy-agushie: a residual by-product of soymilk production. Food Science & Nutrition. 2016;4(2):315-21.

44. Alozie Yetunde E, Udofia US. Nutritional and sensory properties of almond (Prunus amygdalu Var. Dulcis) seed milk. World Journal of Dairy & Food Sciences. 2015;10(2):117-21.

45. Marshall MR. Ash analysis. Food analysis: Springer; 2010. p. 105-15.

46. Ertan K, Bayana D, Gokce O, Alatossava JT, Yilmaz Y, Gursoy O. Total antioxidant capacity and phenolic content of pasteurized and UHT-treated cow milk samples marketed in Turkey. Academic Food Journal. 2017;15(2):103-8.

47. Chávez-Servín JL, Andrade-Montemayor HM, Vázquez CV, Barreyro AA, García-Gasca T, Martínez RAF, et al. Effects of feeding system, heat treatment and season on phenolic compounds and antioxidant capacity in goat milk, whey and cheese. Small Ruminant Research. 2018;160:54-8.

48. Apostolidis E, Kwon Y-I, Shinde R, Ghaedian R, Shetty K. Inhibition of Helicobacter pylori by fermented milk and soymilk using select lactic acid bacteria and link to enrichment of lactic acid and phenolic content. Food biotechnology. 2011;25(1):58-76.

49. McClements DJ, Newman E, McClements IF. Plant-based milks: A review of the science underpinning their design, fabrication, and performance. Comprehensive Reviews in Food Science and Food Safety. 2019;18(6):2047-67.

50. Ogori AF, Amove J, Aduloju P, Sardo G, Okpala COR, Bono G, et al. Functional and Quality Characteristics of Ginger, Pineapple, and Turmeric Juice Mix as Influenced by Blend Variations. Foods. 2021;10(3):525.

51. Amenu K, Agga GE, Kumbe A, Shibiru A, Desta H, Tiki W, et al. Milk Symposium review: Community-tailored training to improve the knowledge, attitudes, and practices of women regarding hygienic milk production and handling in Borana pastoral area of southern Ethiopia. Journal of dairy science. 2020;103(11):9748-57.

52. Niero G, Penasa M, Currò S, Masi A, Trentin A, Cassandro M, et al. Development and validation of a near infrared spectrophotometric method to determine total antioxidant activity of milk. Food chemistry. 2017;220:371-6.

53. Niero G, Currò S, Costa A, Penasa M, Cassandro M, Boselli C, et al. Phenotypic characterization of total antioxidant activity of buffalo, goat, and sheep milk. Journal of dairy science. 2018;101(6):4864-8.

54. Michlova T, Dragounova H, Horníčková Š, Hejtmankova A. Factors influencing the content of vitamins A and E in sheep and goat milk. Czech Journal of Food Sciences. 2015;33(1):58-65.

55. Yilmaz-Ersan L, Ozcan T, Akpinar-Bayizit A, Sahin S. Comparison of antioxidant capacity of cow and ewe milk kefirs. Journal of dairy science. 2018;101(5):3788-98.

56. Baghbadorani ST, Ehsani MR, Mirlohi M, Ezzatpanah H, Azadbakht L, Babashahi M. Antioxidant capability of ultra-high temperature milk and ultra-high temperature soy milk and their fermented products determined by four distinct spectrophotometric methods. Advanced biomedical research. 2017;6.

57. Naik L, R A, Sharma A. Salubrious Curcumin Fortified Whey Beverage Formulation and Study its Antioxidant Property. International Journal of Science, Engineering and Management. 2018;3(6):1-7.

CHAPTER 6

General discussion

6.1 Introduction

Even though the only SDG that explicitly includes nutrition is SDG two: "*End hunger, achieve food security and improved nutrition, and promote sustainable agriculture*", nutrition remains a crucial element for accomplishing all the 17 SDGs. For instance, an unhealthy diet is predisposed by numerous demographic variables and food insecurity, which are traceable to communal conflicts and poverty (SDG one). Dietary choices are also crucial for optimal wellness, SDG three. Better nutrition quality has similarly been linked to education, occupation, and economic growth, SDGs four and eight.[1] Consequently, the production, processing, and consumption of local agricultural resources for healthy living as shown in Figure 6.1 and the attainment of SDGs using the food and nutrition system's inputs, transformations, and outputs are worth investigating. This investigation is particularly relevant in large, densely populated and culturally highly diverse developing countries like Nigeria.

The government of the Federal Republic of Nigeria is working towards achieving the Sustainable Development Goals (SDGs) aimed at ending poverty in all its forms in the year 2030 by strengthening agriculture as the nation was unprepared for the present crude oil shocks. For more than five decades, oil has recorded an average of 95% of export earnings after switching from agriculture to crude oil exportation shortly after independence. Foreign exchange earnings from agri-foods have remained remarkably stable, averaging only 5% up until 2017.[2] In 2017, Nigeria inaugurated an economic policy programme called the 'Economic Recovery and Growth Plan (ERGP)' to diversify its economy and reduce its exposure to global shocks.

The ERGP mainly focuses on the country's self-sustenance, but agricultural production and exports were also highlighted in the policy plan. The cocoa bean, sesame seeds, and cashew nuts were the top three among the ten most exported agricultural products. Cocoa was primarily exported to Germany and the Netherlands, sesame predominantly to China and Japan, and cashew nuts primarily to Vietnam and India. Palm oil, spices, mainly ginger (*Zingiber officinale*), and fruits were the last three among the ten most exported agricultural products.[3]

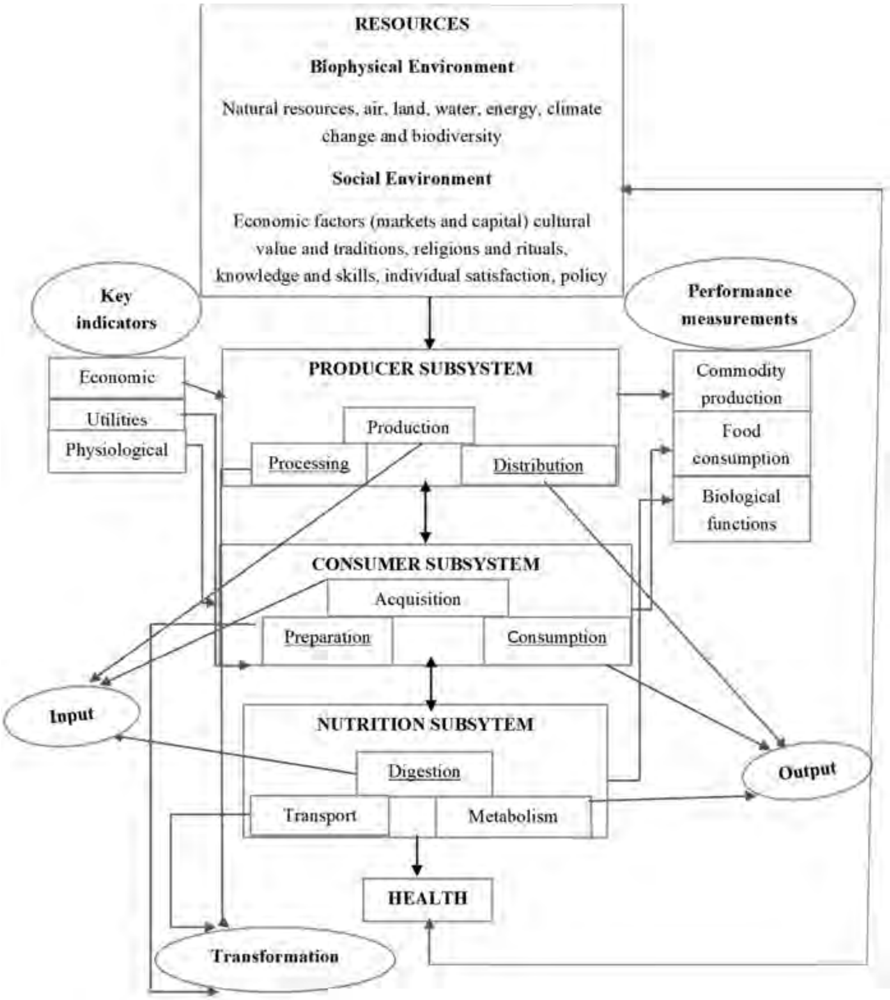

Figure 6.2: Unified food and nutrition system with the areas studied in this thesis underlined. Adapted from Sobal, Khan [4] and Bogard, Marks [5]

The recognition of the importance of Nigerian herbs and spices in the international market advanced research on turmeric (*Curcuma longa*) in Nigeria. Particularly, the Nigerian government is also stimulating research on turmeric as one of the agricultural commodities that seems useful in achieving the SDG goals.[6] Turmeric is a nutritionally rich natural food product.[7] Turmeric has also been identified as an essential nutraceutical and is an extensively researched crop because of its antibacterial, anti-inflammatory, and anti-cancer properties, in addition to its antioxidant characteristics.[8-10]

However, the utilisation of turmeric locally needs to be improved further. Insight into processing, value addition, and consumers' needs and wishes are required to optimise the use of turmeric locally in Nigeria. This insight can be gained by examining how turmeric can be used to enrich foods, for example, street-vended foods. Enriching street-vended foods with turmeric could serve as a means to reach large parts of the population both in developing and developed nations. This thesis project thus used two common drinks from both regions (i.e., *zobo* (*H. sabdariffa*) drink and soya milk) and fortified them with turmeric to study the supplementation of turmeric in street-vended foods. Specifically, the thesis examined the effect of processing and the food matrix on the antioxidant and nutritional quality of turmeric-fortified street-vended *zobo* drinks and soya milk. Additionally, curcumin bioaccessibility in these drinks was explored.

Overall, the specific objectives of the thesis were to:

- Collect and evaluate worldwide information about methods of processing and utilisation of turmeric;
- Critically review studies on how consumers appreciate the use of turmeric in all sorts of food products;
- Examine the consumer acceptability and attitudes of Nigerians to novel turmeric-fortified drinks;
- Investigate to what extent the addition of turmeric can improve the nutritional and antioxidant qualities of the developed turmeric-fortified street-vended drinks; and
- Assess bioaccessibility of curcumin in turmeric-fortified street-vended drinks.

The relevance of the thesis findings in the context of the use of turmeric in street-vended drinks in Nigeria, as well as the extent to which the objectives have been reached, are addressed in this discussion chapter and summarised in Table 6.1. The contribution of this project to the food and nutrition system and possibilities for further research are also discussed using an integrative approach.

6.2 Food and nutrition systems

According to Haddad, and Hawkes,[11] Nigeria's food system provides a limited choice of affordable foods while currently, natural resources consumption occurs in a non-sustainable manner.

Table 6.1: Summary of this thesis' findings

Objective Background investigation	Findings
Chapter 2	
• To determine the optimal food matrices concerning the quantity of turmeric in food that consumers liked best and the validity of the approach to promote turmeric as a new food ingredient.	• Turmeric inclusion in Nigerian staple foods offers new promising options based on the validated formulations and consumer appreciation of turmeric-fortified traditional and ethnic foods in various countries.
Chapter 3	
• To determine the consumer acceptability of newly developed food products with turmeric. • To determine Nigerian consumers' attitudes toward innovative drinks and gain insight into their food neophobia level.	• The sensory evaluation of all turmeric concentrations in the turmeric-fortified *zobo* and soya milk indicated that a healthy diet could be encouraged in Nigeria by fortifying familiar street-vended foods with turmeric. • Food neophobia was most prevalent among Nigerians who fit two demographic profiles: males and those with a high level of education. • Public figures in Nigeria may have a supportive social influence on the acceptance of new drinks.
Chapter 4	
• To determine the effect of processing (boiled turmeric root and turmeric paste added to *zobo* in various quantities) on the nutritional and antioxidant profile of *zobo* drink.	• The nutritional and antioxidant quality of *zobo* drink can be enhanced by processing and adding turmeric as a new ingredient, which the street food vendors in Nigeria could easily adapt. • Including 2% boiled turmeric in street-vended *zobo* can benefit the Nigerian diet due to its high contents of anthocyanins and vitamin C.
Chapter 5	
• To assess the effect of changing the food matrix (cow milk vs soya), amount of turmeric paste (0%, 2% and 6%), and the impact of heating (with and without) on the nutritional and chemical properties of the so-called golden milk.	• The phenolic compounds, antioxidant activity, and protein and iron contents increased with 2% and 6% turmeric in soya milk.

6

The food and nutrition system must be safe, self-sufficient, controllable, accessible, affordable, adaptable, food-secure and sustainable. The food and nutrition system as described explicitly by Sobal, Khan[4] is "the set of operations and processes involved in changing raw materials into foods and transforming nutrients into health outcomes, all of which acts as a system within biophysical and sociocultural contexts." An integrated food and nutrition system is shown in Figure 6.1, in which the outcomes included in this thesis are underlined. The underlined elements viz, distribution, processing, preparation, consumption and digestion as related to this thesis are depicted in Figure 6.2. The chapters in which they are reported are shown in the figure. The *producer subsystem* (Figure 6.1) in developed societies such as in the European Union (EU) focuses on crop and food production for consumption by others. Transforming raw agricultural goods and foods into products and nutrients that may be distributed (i.e., the producer's subsystem output) to homes for preparation or to be eaten directly is a tradition in developed countries, with manufacturers aiming for profits from value-added products.

In contrast, in developing regions like in African Union (AU) many indigenous crops are underutilised or only produced for self/family consumption. Farmer-focused programs that focus on the producer subsystem input (production) and the transformation of the input through processing can promote diet diversity and the intake of the accompanying micronutrients that are low in the diets of Sub-Saharan Africa (SSA) societies. Turmeric is one of those neglected and underutilised crops grown in Africa.[12, 13] An increase in smallholder turmeric output in Africa can lessen poverty. It may boost earnings and allow the turmeric growing communities to buy more health-supporting foods like fruits, vegetables, and animal products. Investigation into how turmeric farmers and processors could be attracted to produce and enrich local foods to meet the population's nutritional needs is thus a knowledge gap filled in this study, Figure 6.2.

The distribution stage transfer output from production and processing through several channels to sites where food is acquired in the *consumer subsystem*, Figure 6.1. Many distribution channels exist in the EU while conventional marketing channels, such as open markets, locality stores, and street food vendors, continue to dominate distribution channels in developing countries, Figure 6.2.

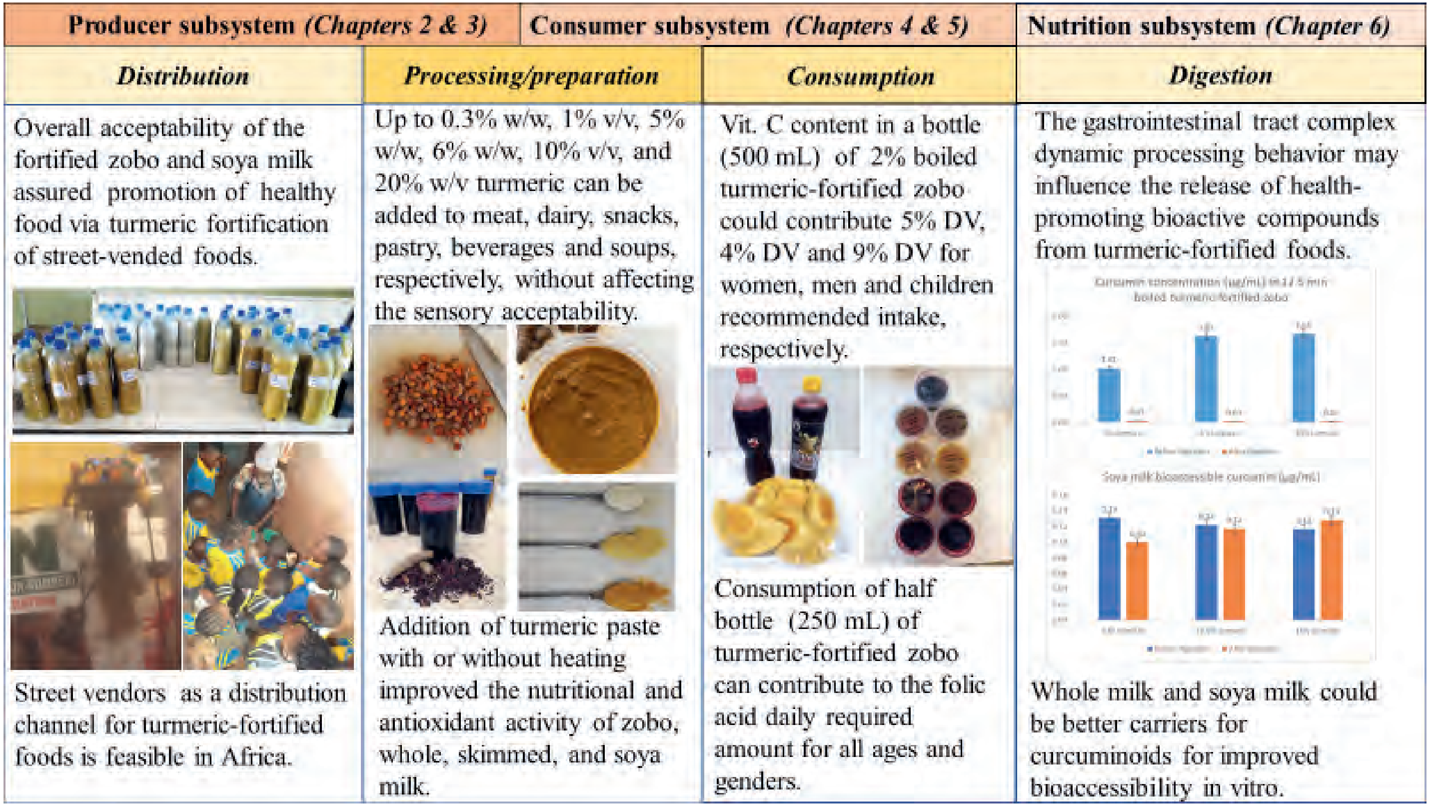

Figure 6.2: Overview of the food and nutrition subsystems reported in this thesis

6

Numerous extensive drivers and tendencies influence distribution channels and consumer demand for food in the AU region. Such drivers include a growing population, income discrepancies, a large number of youths, migration and rapid urbanisation.[14]
Access to safe food, preparation, and consumption are all key factors of enhanced nutrition in the consumer subsystem. As a result, physiological needs for consuming enough nutrients and avoiding harmful toxins are unified into the food and nutrition system, Figure 6.1. The *nutrition subsystem* consists of the digestion, transport, and metabolism phases. For optimum health, a person's body must correctly utilise food and its micronutrients. This study employed a food-to-food fortification approach to delivering the required micronutrients to the populace without radically changing food processing and consumption patterns, Figure 6.2.

6.3 Role of street food vendors as a distribution channel for turmeric-fortified foods

Several studies in Africa have shown that street food vendors play a critical role in Africans' food security and nutrition, especially in locations where modern infrastructure is lacking.[15, 16] According to research in Nigeria, street foods accounted for more than 60% of daily food intake.[17, 18] As shown in Figure 6.3, Nigerians, young and old, like citizens of other developing countries, enjoy a wide range of food sold on the street and in public locations. It is also common in Nigeria to give schoolchildren money to buy foods and drinks at lunch from street food vendors instead of parents preparing food, snacks, or local/traditional beverages, Figure 6.3. As a result, street-vended foods and beverages have the potential to contribute to the diet of schoolchildren considerably. Hence, the majority of street-vended food studies in the region focus on hygiene and food safety situations. These are less of a concern in developed nations, where educational levels, health literacy, and mindfulness are advanced.

Research on the setting of the street-vended food, focusing on its availability, consumption habits, and nutritional adequacy, is significant in the context of noncontagious disease prevention in developed nations, where the obesity pandemic and associated diseases are of major concern. This is not to say that street-vended foods are not popular in developed nations, **chapter 1**. Indeed, street-vended food may be regarded as a prevalent meal alternative and an important element of people's daily food intake in various places in these nations, even though it has yet to be researched in-depth as reported in the scientific literature.[19]

Consequently, due to their widespread use, studies have recommended the possibility of employing street-vended foods as means of micronutrient fortification to combat malnutrition, a situation that is alarming and has persisted over decades in the developing region.[20, 21] Consumer acceptance of the street-vended drinks fortified with turmeric was thus considered in **chapter 3.** The 83% of the respondents who participated in this study liked turmeric-fortified drinks for appearance, mouthfeel, and overall acceptability for all turmeric concentrations used. The drinks (*zobo* and soya milk) fortified with turmeric in this research are generally produced and sold in 500 ml bottles by the street food vendors in Nigeria. These are commonly consumed drinks across all ethnicities in the whole country and even in other countries within and outside Africa.[22] Street food vendors have also been identified as one of the sub-sectors of the informal sector in Africa.[23] The roles of street food vendors in the economy of these countries cannot be underestimated.[21]

For instance, in Nigeria, International Monetary Fund reported that the informal sector increased at an annual pace of 8.5% between 2015 and 2017, accounting for 65% of GDP. The number had not changed before the commencement of the 2020 global pandemic.[24] Thus, street food vendors could be trained to gain insight into how turmeric can be added to *zobo* and soya milk. The training of street food vendors is practicable in Nigeria as demonstrated by several such activities that have been done and are still ongoing in Nigeria.

Figure 6.3 Food vendors at a primary school and train station in Ijoko, Ogun State, Nigeria

Zobo drink production and preservation has been identified as a training course at the Federal Institute of Industrial Research Oshodi (FIIRO), Nigeria.[25] Fasoyiro, and Obatolu [26]

specifically reported that 92% of the processors/vendors had above-average scores when evaluating the training results on improved processing, packaging, storage of soya products and food safety practices among local processors and vendors in South-west Nigeria. The Institute of Agricultural Research and Training (IAR&T) in Ibadan, Nigeria, recently introduced soya beans to high schools and trained them to process and package them into various products for inclusion in everyday diets and selling.[27] Therefore, in Nigeria, as in many other developing nations, the informal street food sector (street food vendors to be precise) is a large sector that can be exploited to disseminate the outcomes of this study to the general public.

6.4 Food-to-food fortification

In SSA, poor families typically eat basic staple-based meals. They frequently lack access to animal-source meals (fish, meat, eggs, and dairy products) and micronutrient-dense foods like fruits, and vegetables. Regarding the effort to reduce malnutrition in developing countries, street-vended foods have been identified as a promising source of micronutrient fortification.[28] Food-to-food fortification of staples is a popular technique for reducing micronutrient deficiencies because of its dominance in developing countries' agricultural systems and consumer diets. Maize, sorghum, rice, wheat, cassava, sesame, tomatoes, yam, cowpea, soya beans, cocoa, palm oil, hibiscus, cashew, potatoes, cotton, and sugar cane are among the priority staple crops identified by the Nigerian government in its National Agricultural Technology and Innovation Plan (NATIP) 2021–2024.[29] Traditional high-nutrient local produce, as well as wild crops, are frequently underutilised and disregarded. Hence more research on food-to-food fortification using these neglected crops and food ingredients rich in bioactive compounds (turmeric in this study case) to reduce micronutrient shortages and improve the bioavailability of crucial bioactive chemicals will be beneficial.

6.4.1 Valorisation of local agricultural resources in food-to-food fortification

Table 6.2 depicts how local agricultural resources are currently used to enrich street-vended food and beverages. Increasing the nutritional content of the developing countries' street-vended foods to provide a nutritious and healthier alternative to western snacks that customers will embrace has been the research focus currently. Crops such as soya bean, amaranth, acha, bambara nut, and carrot have been used in these studies.[30-32]

Evolving from basic research to actual use has led to the utilisation of phenolic compounds present in natural plants as a predominant means in the processing and design of healthy beverages. Mineral, vitamin, flavonoid, phytate, and phenol levels of *zobo* fortified with various fruits mentioned in Table 6.2 increased significantly.[33] A review also highlighted the possible application of aidan and *zobo* to brew highly flavoured and bioactive *pito* (African sorghum beer). Together with sufficient data from research efforts to strengthen innovation and sustainability, a proposed fortified-*pito* was shown to be promising in the prevention and treatment of diseases.[34] Fortified *pito* consumed with bioactive substances could help to alleviate nutritional inadequacies faced in SSA. A study further proved that as the fruits were added, the protein, lipid, and carbohydrate content of fortified *pito* increased significantly. The physicochemical, mineral, and vitamin contents also increased.[35]

The addition of plants rich in natural antioxidants and phenolics such as cocoa (*Theobroma cacao*), tea (*Camellia sinensis*), rosemary (*Rosmarinus officinalis*) to enrich cow and soya milk is also increasingly being studied.[36-38] The green coffee extract fortification of soya milk was successful in increasing the phenolic content and antioxidant potential of a novel functional drink. Phenolic antioxidants from GCE-soya milk were highly bioaccessible in vitro.[38] Besides these local resources, research on enriching street-vended foods with turmeric could play a key role in combating malnutrition and increasing nutritional status. Turmeric, it should be noted, not only colours/flavours the meal it is added to, but it can also boost the antioxidants and nutritional quality.

The major advantage of using local resources in fortification is that the crops are cheap and widely available. Culturally relevant adjustments can be made via food-to food fortification without increasing the price of these street-vended foods and beverages while also boosting their nutritional contents.[39] Though food-to-food fortification has the potential to be a very cost-effective public health intervention, a clear necessity is that the fortified food(s) be consumed in sufficient quantities by a high proportion of the population's target individuals. How this shortcoming could be addressed was reported in **chapter 3**. The connection between SDG four (i.e., quality education) and nutrition (i.e., increased education awareness may influence healthy dietary choices) was apparent in the outcome of **chapter 3**. By examining respondents' attitudes toward various demographic features, practical insights into introducing innovative foods to Nigerian consumers were provided. Overall, promotions by social influencers appear to be a promising strategy for combating food neophobia in Nigeria.

Table 6.2: Food-to-food fortification of street-vended foods

Street-vended food/drink	Local resources used for enrichment	References
Masa (æbleskiver, *poffertjes*, *idli)*	- Bambara groundnut	[40]
	- Acha, soya bean and crayfish	[41, 42]
	- Grain amaranth and carrot powder	[43]
Pito (sorghum beer)	- Orange, banana, pineapple	[34]
	- Aidan fruit (*Tetrapleura tetraptera*), *zobo* (*Hibiscus sabdariffa*) and moringa	[44]
Zobo (roselle)	- Pineapple, orange, ginger and cloves	[33]
	- Ginger and garlic	[45]
Soya milk	- Green coffee	[38]

6.4.2 Turmeric for advancing livelihoods through better nutrition

The inclusion of turmeric in staple foods is increasing globally due to the growing consumer knowledge of the link between health, well-being, and food choices. **Chapter 2** critically reviewed fifty-three articles on consumers' appreciation of foods with added turmeric. Adding turmeric to food could be a food-to-food fortification strategy that will result in improving the population's micronutrient level very quickly. The knowledge gap on processing, utilisation and the extent of turmeric consumption in Nigeria needs to be filled. Thus, we investigated the possibilities of strengthening the utilisation of turmeric to improve the livelihoods of rural communities in Nigeria.

According to the Nigerian respondents, the turmeric rhizome is washed and ground into paste but sometimes dried (without any prior heat treatment) and ground into powder. The processing method conforms to the method described by American Spice Trade Association ASTA[46] which involved sorting, washing, and particle size reduction by longitudinal splitting, drying, milling and sieving. Comparing this method to the information given by the Indian respondents, turmeric processors in India based their procedure on the traditional Indian turmeric processing method: "Separation of fingers from mother rhizome - boiling (45-60 min) – drying – polishing – colouring – packing", which also conforms to the official standard procedure of boiling the rhizome for 45 to 60 min in water until a distinctive turmeric aroma is produced as approved by the Indian Institute of Spice Research in Calicut, Kerawa.[47] The south Indian respondent, who gave full details of the processing method commonly used in India, was a small-scale processor. He had no idea about the equipment's specifications or the particle size of his final product.

The respondents from the two countries consumed turmeric in various forms to impart colour, taste, flavour, and health purposes. All the Indian respondents stated that food is incomplete without turmeric. Turmeric is used in all Indian cuisine and is one of the chief ingredients in curries in India. Unlike what was found among Indian respondents, Nigerian respondents preferred adding turmeric powder only to taste and enhance the cooking flavour. None of the respondents from the two countries knew about any street food in which turmeric is the primary ingredient. Instead, the respondents for the Belagavi district noted that turmeric is used during a festival. This festival is celebrated only with turmeric, and it is called "Somvati Utsav" (Somvati festival). More specifically, the Indian respondents stated that turmeric is commonly mixed with milk (*haldi doodh*), boiled and drank to get rid of throat infections. Nigerian respondents also added dried/powder turmeric to drinks (e.g., lemon juice, fruit juice, and even gin) to make medicinal concoctions (*agbo*) because they were told by their (grand)parents that turmeric helps in the digestion of food. Furthermore, Nigerian respondents also appreciate the bitterness of turmeric and use it in herbal medicinal concoctions for malaria, yellow fever, ulcers, and liver disorders. Overall, turmeric is consumed for healthy living in both countries, in water-based products (*agbo*) in Nigeria and milk-based products (*haldi doodh*) in India.

6.4.3 Relevance of processing

The impact of turmeric addition on the nutritional and antioxidant qualities of street-vended beverages was reported in **chapters 4 and 5**. The effect of processing on these drinks was included in these reports. Turmeric's potential health benefits can be enhanced positively by processing. Food composition and matrix-associated factors such as concentration, nutrient interactions, etc., may also be altered during processing.[48] As a result, processing can substantially impact consumer appreciation, nutritional quality, and the stability and bioaccessibility of turmeric bioactive compounds in turmeric-fortified foods.

Chapter 4 makes a case for the inclusion of turmeric in the street-vended *zobo*; an alcohol-free drink produced from boiling the calyces of *Hibiscus sabdariffa* in water. Since street food vendors are already familiar with boiling *H. sabdariffa* with another local spice, namely ginger, the introduction of boiling *zobo* with turmeric, therefore, seems easily achievable.

Investigating the influence of boiling time and the effect of concentration would have enriched this chapter, but following the *zobo* traditional processing method which we employed in producing our samples led to the current exclusion of such investigation. In addition, turmeric cooking/boiling time as used at home has also been shown to have substantial antioxidant influences.[49]

Since turmeric was added to another street-vended drink (*zobo*) earlier in **chapter 4**, the role of the food matrix in addition to processing was further tested in **chapter 5**. The results of this study showed the effect of a different food matrix, i.e. milk vs. *zobo*, in improving the antioxidant activity of street-vended beverages through turmeric food-to-food fortification. Turmeric did not increase the polyphenol (ferulic and chlorogenic acid) content of *zobo* fortified with turmeric, whether boiled or in a paste form. However, the addition of turmeric increased the Total Phenol Content (TPC) and antioxidant activity of whole milk, skimmed milk, and soya milk, regardless of heat treatment. The effect of heat treatment on turmeric-fortified milk significantly ($p<0.05$) impacted the TPC. Furthermore, compared to whole milk and skimmed milk, soya milk had a higher initial TPC concentration, which is related to the high amount of phenolic compounds in the soya bean. Soya milk tuned out to be the best carrier for turmeric, considering the TPC and total antioxidant activity.

In general, fortification of street-vended *zobo* and soya milk with turmeric was an attempt to improve these beverages' nutritional and health qualities in relation to the antioxidant activity of the phenolic compounds. Our hypothesis that the addition of turmeric would enhance the nutritional and antioxidant properties of street-vended beverages was thus confirmed. However, as reported in the literature,[38] interactions between phenolics and the food matrix may affect the nutritional benefits of turmeric-fortified foods by altering bioactive components during digestion. Also, the impact of digestion and consumer acquisition cannot be excluded from the food and nutrition system; as a result, we studied the *in vitro* bioaccessibility of curcumin in the turmeric-fortified drinks developed in this project.

6.5 Implications for future research and recommendations

This project encouraged turmeric production, processing and consumption for healthy living and the attainment of SDGs using the food and nutrition system's inputs, transformations, and outputs The efforts have resulted in understanding some of the components that influence this phenomenon. However, we believe there is still plenty of room for optimization and study to shed more light on the system's full potential. What will the food and nutrition system look like when turmeric is adopted in street-vended foods? We thus did some preliminary trials on the bioavailability study of the turmeric-fortified drinks. The outcomes of these trials were not included in the research chapters but could open new areas of study regarding turmeric utilisation. We will discuss some of the topics we think are worth researching in this section.

Bioavailability

Processing, consumption, and digestion are stages involved in connecting natural resources to health in the food and nutrition system, Figure 6.1. Regardless of the type of food being investigated, the bioavailability of beneficial compounds is crucial for dietary efficiency and thus requires assessment. The health benefit of turmeric has been explicitly linked to curcumin.[50-52] Case-specific assessment is needed because results will be different when curcumin is investigated in isolation instead of in the whole turmeric, where curcumin is present alongside other bioactive compounds in their natural environment. Furthermore, synergistic interactions and structure play a role in the bioavailability of curcumin. To date, limited studies have reported the food matrix effect and how foods naturally interact synergistically on curcumin bioavailability. Bioactive bioaccessibility is a prerequisite for their bioavailability.[53] Thus, the bioaccessibility of curcumin in the turmeric-fortified street-vended drinks reported **in chapters 4 and 5** was explored.

In this exploration, the concentration of curcumin remained slightly stable irrespective of the concentration of turmeric added to *zobo*. There are two possible pathways available for curcumin in the digestion system. The first mechanism is discussed in this experiment, where the digestive system directly digested free curcumin in drinks, and the degraded product was produced. Secondly, using delivery systems to encapsulate curcumin creates protection and improves bioaccessibility, while bioavailability still depends on the permeability of the gastrointestinal tract. Various types of research have been conducted in recent years to overcome the issue, primarily focusing on improving curcumin's bioavailability through multiple delivery systems, such as nanoparticles, liposomes, micelles, etc. These delivery systems strengthen the stability and water solubility of oil-soluble curcuminoids.[54] Still, the technology involved may be too complicated and expensive for street food vendors and small-scale food processors targeted in this thesis. Thus the bioavailability of curcumin was further explored in another food matrix, namely cow milk and the plant analogue soya milk.

The curcumin content increases with an increase in concentrations before and after digestion in whole milk. Although the mechanism of exogenous lipids' effect on the solubilisation capacity of lipophilic substances is still unclear,[53] the exploration showed that lipids in whole milk and its plant analogue (soya milk) could improve the curcuminoids solubility in the intestinal aqueous environment, hence increasing their bioaccessibility. The explorations showed that whole milk and soya milk could be better carriers for curcuminoids for improved bioaccessibility *in vitro*.

Lastly, the bioavailability of curcumin can be increased with changes in the sample ingredient formulations. Therefore, additional ingredients can be added to turmeric-fortified drinks to increase curcumin's antioxidant activity and bioavailability. Piperine, found in black pepper, is an example of such a compound known to increase the bioavailability of curcumin. Further research could be done on the effect of adding additional ingredients on curcumin bioaccessibility and thus improving the recipe and preparation of turmeric-fortified water-based drinks like *zobo*.

Food Fraud

Scientifically, it seems irrational to add colour to a product like a turmeric powder that already has such a bright yellow colour. Thus we tried to hypothesize what this might be? Perhaps a knowledge that could be transferred to Nigerian turmeric processors but the Indian respondent withheld the name in the survey study. Instead of disclosing the name, he mentioned that all the Indian processors basically add a colouring agent to gain value in the market, and then we suspected food fraud practices.

Food fraud can take several forms, one of which is the inclusion of prohibited or unreported additives to hide damage or inferiority in the raw materials, as well as to boost the quantity of the finished product. This is perhaps the case with turmeric adulteration. Thus, artificial colour is deceptively added to turmeric to hide damages and losses during the peeling, boiling and polishing phases. Furthermore, dried turmeric wholesalers regard the bright yellow colour of turmeric to be one of the most sought quality attributes. This trait could also serve as a motivator for fraudsters to mess with turmeric by adding lead chromate ($PbCrO_4$). Lead chromate could also conceal any stains or deterioration of the roots. Additionally, due to its vibrant yellow colour, literature has reported a scenario of Bangladesh processors adding lead chromate to turmeric to please wholesalers who prefer to sell and export brighter turmeric from India.[55] Thus, we implicit the colouring agent the Indian processor refused to give the details could be lead chromate. According to Erasmus et al.,[56] turmeric adulteration with lead chromate is frequently reported in the media as having occurred among the processors in turmeric-producing countries. Even though this is true in certain circumstances, it is crucial to emphasise that traditional processing methods vary by country.

Turmeric has not been thoroughly studied for adulteration despite its widespread use and consumption, however, it has been recognized as a source of lead exposure in South Asia. Adulteration of turmeric with lead chromate should be public health concern not only for the developing countries but also for the Western world because the majority of turmeric is imported from emerging markets. We recommend more research into the adulteration of turmeric with lead chromate, a bright yellow, poisonous, and carcinogenic chemical.

Street-vended foods' role in nutrition intervention strategies

Though essential, the role of street-vended foods in intervention strategies on nutrition and contributions to achieving food security has not received the attention it deserves.[19, 28] Considering the significance of street food to a substantial fraction of the global population, more and more validated scientific study is recommended to understand all areas of street-vended foods in diverse settings. Particularly in terms of street food nutritional value as well as availability and consumption pattern. Thus, the recommended study includes:

- Adopting turmeric in other street-vended drinks and foods like Nigerian *kunnu* (Americans and Spanish *smile de jicaro* and *horchata*), *burukutu* and *pito* (brewed sorghum), *masa* (maize/rice flour pancake), *beske* (soya cheese) etc., could also be explored.
- Flavourful combinations of fruits and spices, such as turmeric, may result in ideal nutritional characteristics. Adelekan, Arisa[35] and Akujobi, Obicheozo[33]for example, enhanced *zobo* by adding various fruits to it. Hence we recommend testing if the nutrient improvement can be optimised by combining turmeric and other fruits in the *zobo* drink.
- The analysis of vitamin C, delphinidin-3-sambubioside, and cyanidin-3-sambubioside, could be furthered to understand why 2% boiled turmeric in *zobo* contains significantly higher vitamin C and anthocyanin values when compared to 6% boiled turmeric in *zobo*. Research regarding the aggregation or precipitation phenomena in turmeric-fortified *zobo* at higher concentrations of turmeric could thus be carried out.
- *Zobo* contains a variety of health-promoting compounds in addition to minerals and vitamins. For instance, lutein, which may help prevent macular degeneration, is also involved in developing a fetus' visual and neurological systems and has antioxidant

characteristics.[57] *Zobo* also has a high concentration of anthocyanidins, which may provide health benefits due to their antioxidant properties.[58] We thus recommend measuring the concentration of these and other healthy components to know a broad overview of the nutritional and antioxidant profile of the turmeric-fortified *zobo*.

- Heat treatment influences the protein content of soya milk, and proteins can increase the nutritional quality but decreases the essential amino acids when heated for a longer time. Further study is desirable to understand the influence of heat treatment on the proximate analysis of soya milk since information on this part is limited.
- During the measurement of the TPC with the Folin-Ciocalteu test, the values of the TPC were lower than values from other studies done on similar milk types. Further research is recommended to analyse the TPC of liquid turmeric-fortified milk samples and compare these results with the result found in this research with freeze-dried turmeric-fortified milk samples. This way, the influence of freeze-drying on the measurement of the phenolic content can be determined.
- Finally, we used Food Attitude Survey (FAS) instrument for the food neophobia study conducted in this research because of motivation for the study was to support the acceptance of new (unfamiliar) foods to improve the nutritional health of consumers. Thus, recommend more research utilising other instruments such as the Food Eating Survey, Variety Seeking Tendency Scale (VARSEEK), Food Technology Neophobia Scale (FTNS), and Food Neophobia Scale (FNS) to understand food neophobia among African better and to study African attitudes towards food-to-food fortification.

6.6 Concluding remarks

Street-vendor dishes are produced daily for sale in markets, offices, schools, and parking lots, as well as drinks like *zobo* as supplements and complements to soft drinks that are too expensive for the locals and on occasions such as weddings, naming ceremonies, Muslim *Eid-al- Fitr*, Christmas, and condolences since they are well appreciated by all religions and ethnic groups in Nigeria. As a result, the street food industry is a vital driver of economies in Nigeria that deserves more research attention. Many people without regular jobs resort to it as their primary source of income to improve their lives. This sector of the foodservice industry has played and will continue to play, a significant role in guaranteeing the availability of affordable and convenient foods for Nigerians, hence, supporting food security and reducing hunger. This research revealed a possible source of micronutrients fortification utilising *zobo* and soya milk. The outcomes of this study demonstrated the impact of processing and different food matrixes on enhancing the antioxidant activity of these two beverages via turmeric food-to-food fortification. Ultimately, the impact of the food matrix and the co-presence of turmeric compounds on the bioaccessibility of curcumin was established in this study. This project thus demonstrated how Sustainable Development Goals (SDGs) could be achieved through the promotion of health-supporting food using local resources, namely turmeric. This study also provides a launch point for studying food neophobia among Nigerian consumers regarding the fortification of street-vended drinks. Researchers seeking to improve the African population's nutritional status by producing healthy foods for inclusion in the diet might profit from such information. Finally, given the turmeric processing limitations revealed by the comparison of the practices in Nigeria and India, developing a standardized processing method, suitable infrastructure, and processing equipment will be advantageous in obtaining high-quality turmeric powder in Nigeria.

References

1. Grosso G, Mateo A, Rangelov N, Buzeti T, Birt C. Nutrition in the context of the Sustainable Development Goals. European Journal of Public Health. 2020;30(Supplement_1):i19-i23.

2. Zdráhal I, Verter N, Daňková B, Kuchtík J. 'Products mapping and agri-food trade between Nigeria and ECOWAS member countries. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 2019;67(5):1379-92.

3. Verter N. Analysis of external influences on agricultural performance in Nigeria. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 2016;64(5):1805-21.

4. Sobal J, Khan LK, Bisogni C. A conceptual model of the food and nutrition system. Social Science & Medicine. 1998;47(7):853-63.

5. Bogard JR, Marks GC, Wood S, Thilsted SH. Measuring nutritional quality of agricultural production systems: Application to fish production. Global food security. 2018;16:54-64.

6. Nwaekpe J, Anyaegbunam H, Okoye B, Asumugha G. Promotion of turmeric for the food/pharmaceutical industry in Nigeria. Journal of Experimental Agriculture International. 2015;8(6):335-41.

7. Ahmad RS, Hussain MB, Sultan MT, Arshad MS, Waheed M, Shariati MA, et al. Biochemistry, safety, pharmacological activities, and clinical applications of turmeric: A mechanistic review. Evidence-based Complementary and Alternative Medicine. 2020;2020.

8. García-Casal MN, Pena JP, Malavé, HG. Sauces, spices, and condiments: definitions, potential benefits, consumption patterns, and global markets. Annals of the New York Academy of Sciences. 2016;1379(1): 3-16.

9. Hay E, Lucariello A, Contieri M, Esposito T, De Luca A, Guerra G, et al. Therapeutic effects of turmeric in several diseases: An overview. Chemico-biological Interactions. 2019;310:108729.

10. Verma RK, Kumari P, Maurya RK, Kumar V, Verma R, Singh RK. Medicinal properties of turmeric (Curcuma longa L.): A review. International Journal of Chemical Studies. 2018;6(4):1354-7.

11. Haddad LJ, Hawkes C, Achadi E, Ahuja A, Ag Bendech M, Bhatia K, et al. Global Nutrition Report 2015: Actions and accountability to advance nutrition and sustainable development: Intl Food Policy Res Inst; 2015.

12. Mane R, Pawar V, Kshirsagar R. Studies on development of process technology for formulation, sensory evaluation and storage studies of fresh turmeric rhizome juice-based orange RTS beverage. International Journal of Chemical Studies 2019;7(1):1704-9.

13. Olojede A, Iluebbey P, Dixon A. IITA/NRCRI Collaborative Germplasm and data collection on minor Root and Tuber Crops in Nigeria. Annual Report. 2005:77-81.

14. Staatz J, Hollinger F. West African food systems and changing consumer demands. OECD Publishing. 2016;4:1-26.

15. Battersby J. Looking backwards to go forward. Gastronomica: The Journal for Food Studies. 2020;20(1):19-20.

16. Alimi BA. Risk factors in street food practices in developing countries: A review. Food Science and Human Wellness. 2016;5(3):141-8.

17. Anyasor OM. Consumer Motivations and Patronage of Street Food Vendors in South-East of Nigeria. Edwin Okey Umeanyika, EO, Prof Eze, PA, Anyasor, OM & Anetoh, JC (2021) International Journal of Economics and Business Management. 2021;7(2):33-42.

18. Oguntona C, Tella T. Street foods and dietary intakes of Nigerian urban market women. International Journal of Food Sciences and Nutrition. 1999;50(6):383-90.

19. Abrahale K, Sousa S, Albuquerque G, Padrão P, Lunet N. Street food research worldwide: a scoping review. Journal of Human Nutrition and Dietetics. 2019;32(2):152-74.

20. Anjorin O, Okpala O, Adeyemi O. Coordinating Nigeria's micronutrient deficiency control programs is necessary to prevent deficiencies and toxicity risks. Annals of the New York Academy of Sciences. 2019;1446(1):153-69.

21. Steyn NP, Mchiza Z, Hill J, Davids YD, Venter I, Hinrichsen E, et al. Nutritional contribution of street foods to the diet of people in developing countries: a systematic review. Public Health Nutrition. 2014;17(6):1363-74.

22. Idowu-Adebayo F, Toohey MJ, Fogliano V, Linnemann AR. Enriching street-vended *zobo* (*Hibiscus sabdariffa*) drink with turmeric (*Curcuma longa*) to increase its health-supporting properties. Food & Function. 2021;12:761-70.

23. Etim E, Daramola O. The informal sector and economic growth of South Africa and Nigeria: A comparative systematic review. Journal of Open Innovation: Technology, Market, and Complexity. 2020;6(4):134.

24. Madichie NO, Gbadamosi A, Rwelamila P. Entrepreneurship and the Informal Sector: Challenges and Opportunities for African Business Development. Taylor & Francis; 2021.

25. Omoarukhe ED. Natural processing for beverages: from a Hibiscus sabdariffa (Roselle) beverage perspective: University of Reading; 2017.

26. Fasoyiro S, Obatolu V, Ashaye O, Lawal B. Knowledge assessment, improved storage techniques, and training of local processors and vendors of soy products on food safety practices in South-West Nigeria. Journal of Agricultural & Food Information. 2010;11(4):340-50.

27. Fadairo A, Oyegbami A, Oyedokun M. Determinants of competence in soybean processing among secondary school students in Ibadan, Oyo State, Nigeria. African Journal of Food, Agriculture, Nutrition and Development. 2020;20(1):15252-66.

28. ImathIu S. Street vended foods: potential for improving food and nutrition security or a risk factor for foodborne diseases in developing countries? Current Research in Nutrition and Food Science Journal. 2017;5(2):55-65.

29. Maziya-Dixon B, Achterbosch T, Adelekan D, Adeyemi O, Ajieroh V, Akerele D, et al. Food Systems for Healthier Diets in Nigeria. 2021.

30. Lawal OM, van Stuijvenberg L, Boon N, Awolu O, Fogliano V, Linnemann AR. Technological and nutritional properties of amaranth-fortified yellow cassava pasta. Journal of Food Science. 2021;86(12):5213-25.

31. Chadare FJ, Idohou R, Nago E, Affonfere M, Agossadou J, Fassinou TK, et al. Conventional and food-to-food fortification: An appraisal of past practices and lessons learned. Food Science & Nutrition. 2019;7(9):2781-95.

32. Mubaiwa J, Fogliano V, Chidewe C, Bakker EJ, Linnemann AR. Utilization of bambara groundnut (*Vigna subterranea* (L.) Verdc.) for sustainable food and nutrition security in semi-arid regions of Zimbabwe. PLoS One. 2018;13(10):e0204817.

33. Akujobi I, Obicheozo G, Nwokorie C. Nutrient composition, phytochemical and sensory properties of *zobo* (*Hibiscus sabdariffa*) drinks substituted with pineapple (*Ananas comosus*) and orange (*Citrus sinensis*) juices. Journal of Agriculture and Food Sciences. 2018;16(2):1-13.

34. Adadi P, Kanwugu ON. Potential application of *Tetrapleura tetraptera* and *Hibiscus sabdariffa* (Malvaceae) in designing highly flavoured and bioactive pito with functional properties. Beverages. 2020;6(2):22.

35. Adelekan A, Arisa N, Alamu A, Adebayo Y, Popoola G. Production and acceptability of fruits enhanced *zobo* drink. Food Science and Technology Letters. 2014;5(1):046-51.

36. Qiu X, Jacobsen C, Sørensen A-DM. The effect of rosemary (*Rosmarinus officinalis* L.) extracts on the oxidative stability of lipids in cow and soy milk enriched with fish oil. Food Chemistry. 2018;263:119-26.

37. Gallo M, Vinci G, Graziani G, De Simone C, Ferranti P. The interaction of cocoa polyphenols with milk proteins studied by proteomic techniques. Food Research International. 2013;54(1):406-15.

38. Sęczyk Ł, Świeca M, Gawlik-Dziki U. Soymilk enriched with green coffee phenolics–Antioxidant and nutritional properties in the light of phenolics-food matrix interactions. Food Chemistry. 2017;223:1-7.

39. Patel K, Guenther D, Wiebe K, Seburn R-A. Promoting food security and livelihoods for urban poor through the informal sector: a case study of street food vendors in Madurai, Tamil Nadu, India. Food Security. 2014;6(6):861-78.

40. Balogun MA, Oyeyinka SA, Kolawole FL, Dauda AO, Abdulmalik AJ. Effect of storage period on physical, chemical, microbial, and sensory qualities of instant masa flour produced from blends of rice and Bambara groundnut. Journal of Agricultural Sciences, Belgrade. 2021;66(2):165-79.

41. Samuel FO, Ishola OR, Otegbayo BO. Nutritional and sensory evaluation of rice-based Masa Enriched with Soybean and Crayfish. Food and Nutrition Sciences. 2015;6(02):234.

42. Malomo A, Abiose S. The effect of the substitution of acha (Digitaria exilis) and soybean on the chemical composition and sensory properties of maize masa. Croatian Journal of Food Science and Technology. 2020;12(1):101-9.

43. Akande A, Jolayemi OS, Familusi A, Idowu B. Nutritional, antioxidant and sensory properties of rice-based masa enriched with grain amaranth and carrot powder. Ann Food Sci Technol. 2018;19(4):645-56.

44. Ayirezang FA, Saba CKS, Amagloh FK, Gonu H. Shelf life improvement of sorghum beer (*pito*) through the addition of *Moringa oleifera* and pasteurization. African Journal of Biotechnology. 2016;15(46):2627-36.

45. Adesokan I, Abiola O, Adigun M, Anifowose O. Analysis of quality attributes of *Hibiscus sabdariffa* (*zobo*) drinks blended with aqueous extract of ginger and garlic. African Journal of Food Science. 2013;7(7):174-7.

46. ASTA. A concise guide to spices, herbs, seeds, and extractives. American Spice Trade Association. 2002:48-50.

47. Plotto A. Turmeric: post-production management. Food and Agriculture Organization http://wwwfaoorg/fileadmin/user_upload/inpho/docs/Post_Harvest_Compendium_-_Turmeric pdf. 2004.

48. Fardet A, Rock E. In vitro and in vivo antioxidant potential of milk, yoghurts, fermented milk and cheeses: a narrative review of evidence. Nutrition Research Reviews. 2018;31(1):52-70.

49. Tilak JC, Banerjee M, Mohan H, Devasagayam T. Antioxidant availability of turmeric in relation to its medicinal and culinary uses. Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives. 2004;18(10):798-804.

50. Chen FP, Li BS, Tang CH. Nanocomplexation of soy protein isolates with curcumin: Influence of ultrasonic treatment. Food Research International. 2015;75:157-65.

51. Jin H-H, Lu Q, Jiang J-G. Curcumin liposomes prepared with milk fat globule membrane phospholipids and soybean lecithin. Journal of Dairy Science. 2016;99(3):1780-90.

52. Nasef NA, Loveday SM, Golding M, Martins RN, Shah TM, Clarke M, et al. Food matrix and co-presence of turmeric compounds influence bioavailability of curcumin in healthy humans. Food & function. 2019;10(8):4584-92.

53. Fu S, Augustin MA, Shen Z, Ng K, Sanguansri L, Ajlouni S. Bioaccessibility of curcuminoids in buttermilk in simulated gastrointestinal digestion models. Food Chemistry. 2015;179:52-9.

54. Ji HF, Shen L. Can improving bioavailability improve the bioactivity of curcumin? Trends in Pharmacological Sciences. 2014;35(6):265-6.

55. Forsyth JEN, Islam, SS, Baker, M, Yeasmin, D, Islam, MS, Rahman, M, Fendorf, S, Ardoin, NM, Winch, PJ, Luby, SP. Turmeric means “yellow” in Bengali: Lead chromate pigments added to turmeric threaten public health across Bangladesh. Environmental Research. 2019;179.

56. Erasmus SW, van Hasselt L, Ebbinge LM, van Ruth SM. Real or fake yellow in the vibrant colour craze: Rapid detection of lead chromate in turmeric. Food Control. 2021;121:107714.

57. Steiner BM, McClements DJ, Davidov-Pardo G. Encapsulation systems for lutein: A review. Trends in Food Science & Technology. 2018;82:71-81.

58. Khoo HE, Azlan A, Tang ST, Lim SM. Anthocyanidins and anthocyanins: coloured pigments as food, pharmaceutical ingredients, and the potential health benefits. Food & Nutrition Research. 2017;61(1):1361779.

General Summary

Nigeria is working towards achieving sustainable development goals aimed at ending poverty in all its forms by 2030 by strengthening the role of agriculture. To make this happen, the utilisation of the country's natural resources needs to be improved. Turmeric (*Curcuma longa*) is a resource known for its main constituent, curcumin, which is believed to have antioxidant, antiprotozoal, antiviral, anti-infectious, anti-tumour, anti-metastatic, anti-proliferative, anti-hepatotoxic, anti-venom, and anti-inflammatory properties. However, turmeric is neglected by Nigerian farmers, even though it is largely cultivated in Ekiti and Ondo states of Nigeria. Thus, turmeric is receiving increased research attention in Nigeria for its large potential for rural farmers, local industries, and export. Nevertheless, there is a need for more insight into consumers' needs and wishes as well as an assessment of the problems encountered by turmeric users. Hence, in this research, turmeric was added to street-vended beverages using a method that the street-vended food processors could quickly implement. The nutritional and antioxidant quality of the turmeric-fortified street-vended drinks, consumers' acceptability, and knowledge of food neophobia among Nigerian consumers were reported in this thesis.

The consumer appreciation of novel foods with added turmeric has been studied in different nations, but no meta-analysis has been performed yet. In **chapter 2**, we reviewed 53 articles and tailored the studies on turmeric-fortified foods in diverse countries to suit the Nigerian situation. Consumer appreciation for turmeric-fortified foods was substantially related to the food category. The addition of turmeric was popular in snacks, pastries, beverages, meat and dairy products. Therefore, we expect the review to interest all those looking for an approach towards promoting new food ingredients in the framework of new food product development to meet consumer needs and wants not only in Nigeria but globally. **Chapter 2** stressed that though the golden yellow colour of turmeric-fortified foods has contributed the most to their popularity among consumers, levels of volatiles and phenolic chemicals in turmeric could influence the nutritional and sensory properties of the turmeric-fortified foods.

Food neophobia among Nigerian consumers was examined in **Chapter 3**. Males were shown to have a higher level of food neophobia than females. Respondents with middle-income earners, respondents between the ages of 26 and 35, and respondents with the highest levels of education had a more neophobic attitude toward turmeric-fortified drinks. There is also a scarcity of information about food neophobia among African consumers. However, a thorough study of this subject is required to help people accept new foods, such as when fortifying familiar foods to improve people's health and nutritional status. By paying attention to opinions from respondents with various demographic factors, **chapter 3** provided practical insights into the introduction of novel foods to Nigerian customers. Celebrity endorsement appears to be a promising strategy for combating food neophobia in Nigeria.

In the study described in **chapter 4**, turmeric was added to *zobo* in concentrations of 2% and 6% (w/w) using two processing methods: boiling turmeric rhizomes in *zobo* and adding turmeric paste to the final *zobo* beverage. We showed that fortifying *zobo* with boiled turmeric enhanced the nutritional and antioxidant properties, particularly in terms of vitamin C, iron, and delphinidin-3-sambubioside. Specifically, due to aggregation and/or precipitation of vitamin C and anthocyanins at a higher concentration, only 2% turmeric is required to boil with street-vended *zobo* to benefit the consumer diet. Overall, turmeric did not increase the polyphenol (ferulic and chlorogenic acid) content of *zobo* fortified with turmeric, whether boiled or in a paste form. Thus, the role of the food matrix in addition to processing was tested in turmeric-fortified milk in **chapter 5**. The release of antioxidants from turmeric was examined by adding turmeric paste to milk at varying concentrations (2, and 6% w/v) with and without heating. The results of **Chapter 5** showed the effect of a different food matrix, i.e., milk vs. *zobo*, in improving the antioxidant activity of street-vended beverages through turmeric food-to-food fortification.

The addition of turmeric at 2% and 6% increased the Total Phenol Content (TPC) and antioxidant activity of whole milk, skimmed milk, and soya milk, regardless of heat treatment. The effect of heat treatment on turmeric-fortified milk significantly ($p < 0.05$) impacted the TPC of 6% turmeric in whole milk. However, soya milk turned out to be the best carrier for turmeric, considering the TPC and total antioxidant activity. Plant-based milk made from soya beans serves to release and transport bound antioxidants in turmeric to promote consumer health, **Chapter 5**. The outcome of **chapter 5** further supports the global expansion of soya milk consumption as a vegan substitute for cow milk. Furthermore, it was found in **chapter 5** that if soya milk is heated before consumption, 6% turmeric addition gave the highest antioxidant activity among all the samples. Overall, fortification of street-vended drinks with turmeric will lead to further developments in turmeric production, processing, distribution, and consumption, thereby increasing agricultural production and thus the incomes of small-scale food producers (especially youth, women, and indigenous people), and contributing to a sustainable food and nutrition system.

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"From every wound, there is a scar, and every scar tells a story. A story that says, I survived"
(Fr. Craig Scott)

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I owe my deepest gratitude to my wonderful children and my love. I would not have considered doing a PhD abroad as a healing process if my daughter had not cooperated when I weaned her at seven months to be able to catch up with my MSc. My dear son, your cooperation each time I left you behind helped me this far. I also weaned you abruptly while you were ten months old to attend the IFS workshop in the Republic of Benin, where I heard a lot about Wageningen University. *Ife mi*, thanks for all your support, without which I would have stopped this study a long time ago. You have been amazing. Despite the extra computer screen you bought to keep me at home at weekends in the last year of my PhD study, I needed to check something in the lab to write my rebuttal, changes in VPN settings and so on would make me go to university either on Saturday or Sunday. I will now stop working on campus on weekends as I promised. The thesis is specially dedicated to you to appreciate your understanding, care, and love.

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About the author

Folake Idowu-Adebayo was born in Omuo-Ekiti, Nigeria on November 1st, 1978. She obtained both her BSc in Food Science and Technology and her MSc in Food Quality and Assurance from the Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria in 2004 and 2013 respectively. Folake has had some teaching and research experience at the university level since 2011. Before then, she previously had some industrial experience in food industries at the cottage and multinational industry levels. She has a vision of adding value to neglected tropical crops to improve the livelihoods of youth and women. Her motivation for this vision started during her master's thesis when she conducted a survey on the socio-economic status of fried street-vended cocoyam chip processors in Ogun State, Nigeria. Since then, she has worked on different foods and drinks to improve the nutrition and livelihood of both the processors and consumers. Her PhD thesis is on the economic enhancement and health benefits of the turmeric-growing communities in Nigeria. Her international exposure and demonstrated leadership ability have enabled her to successfully supervise students' theses from Africa, Asia, Europe, and the USA, both at the bachelor's and master's levels.

Folake is a junior faculty member of the USAID-Partnership for Enhanced Engagement in Research (PEER). A Women in Science mentorship program that helped her win USAID SEED grants from the National Academies of Sciences, Engineering, and Medicine in 2018. She is a Fellow Mentee of African Women in Agricultural Research and Development (AWARD). She has attended workshops and conferences locally and internationally with the support of the International Foundation of Science (IFS), European Union-African Caribbean Pacific (EU-ACP), African Women in Agricultural Research and Development (AWARD), Federal government of Nigeria Tertiary Education Trust Fund (TETFund), United States Agency for International Development (USAID), Global Harmonization Initiative (GHI) and Wageningen University and Research WUR-LEB foundation. Folake enjoys reading, travelling, and cooking. folake.idowuadebayo1@gmail.com

List of publications

This thesis

Idowu-Adebayo, Folake, Fogliano, Vincenzo, Linnemann, Anita (2022). Turmeric-fortified cow and soya milk: golden milk as a street food to support consumer health. *Foods* 11 (4).

Idowu-Adebayo, F., Fogliano, V., Oluwamukomi, M. O., Oladimeji, S., & Linnemann, A. R. (2020). Food neophobia among Nigerian consumers: A study on attitudes towards novel turmeric-fortified drinks. *Journal of the Science of Food and Agriculture*. 101 (8) 3246 - 3256. https://doi.org/10.1002/jsfa.10954

Folake Idowu-Adebayo, Mary J. Toohey, Vincenzo Fogliano and Anita R. Linnemann (2020). Enriching street-vended zobo (*Hibiscus sabdariffa*) drink with turmeric (*Curcuma longa*) increases its health-supporting properties. *Food and Function.* 761 – 770 https://pubs.rsc.org/en/content/articlehtml/2021/fo/d0fo02888f

Others:

Oni, O.K., Jaiyeoba, C.N., Adepeju, A.B., Oyinloye, A.M., Ojo, M.O., **Idowu-Adebayo, F**., and Orungbemi, O. (2021). Nutritional assessment of instant poundo yam from yellow yam (*Dioscorea cayenensis*) supplemented with yellow cassava (*Manihot esculenta*) flour. *Journal of Home Economics Research. 28*(1), 30 - 41.

Adeyeye, S.A.O., Bolaji, O.T., Abegunde, T.A., Tiamiyu, H.K., Adebayo-Oyetoro, A.O., and **Idowu-Adebayo, F.** (2020). Effect of natural fermentation on nutritional composition and antinutrients in soya wara (a Nigerian fried soy-cheese). *Food Research.* 4(1), 152 - 160.

Adeyeye, S.A.O., Bolaji, O.T., Abegunde, T.A., Adebayo-Oyetoro, A.O., Tiamiyu, H.K., and **Idowu-Adebayo, F.** (2019). Quality characteristics and consumer acceptance of bread from wheat and rice composite flour. *Current Research in Nutrition and Food Science.* 7(2), 488 - 495.

Lawal, O.M, **Idowu-Adebayo, F,** Enujiugha, V.N. (2018). Nutritional assessment of Nigerian ethnic vegetable soups (Marugbo, Tete and Ila). (2018). *Journal of Nutrition, Food and Lipid Science.* 1(1), 32 - 39. https://doi.org/10.33513/NFLS/1801-05

T.A Shittu, **F. Idowu-Adebayo,** I.I Adedokun and O.Alade (2015). Water vapour adsorption of starch-albumen and rheological behaviour of its paste. *Elsevier Nigerian Food Journal*. 33(1), 90-96. https://doi.org/10.1016/j.nifoj.2015.04.014

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Overview of completed training activities

A: Discipline specific activities

Courses

- Epigenesis and Epigenetics (VLAG/WIAS, Wageningen, The Netherlands, 2017)
- Summer School on Smart Phone Based Food Analysis (VLAG/WIAS, Wageningen, The Netherlands, 2017)
- Food Value Chain Research (VLAG, Wageningen, The Netherlands, 2017)
- Healthy and Sustainable Diets: Synergies and Trade-offs (VLAG, Wageningen, The Netherlands, 2017)
- Sensory Perception and Food Preference: The role of context (VLAG, Wageningen, The Netherlands, 2018)
- Healthy Food Design (VLAG, Wageningen, The Netherlands, 2018)

Conferences and meetings

- 1st World Congress on Food Safety and Security (GHI, Leiden, The Netherland, 2019)*
- 13th Pangborn Sensory Science Symposium (Elsevier, Edinburgh, Scotland, 2019)*
- 33rd EFFoST International Conference (Elsevier, Rotterdam, The Netherlands, 2019)*
- The International Conference of Food Safety and Health (Chung Shan Medical University, Taichung, Taiwan, 2019)**
- 44th Annual NIFST Conference (Lagos, Nigeria, 2020)
- International science-policy event in support of the Sustainable Development Goals (INREF, Wageningen, The Netherlands 2022)

B: General Courses

- 39th VLAG PhD week (VLAG, Baarlo, The Netherlands, 2017)
- Introduction to R (VLAG, Wageningen, The Netherlands, 2017)
- Information literacy for PhD including EndNote introduction (WUR-Library, Wageningen, The Netherlands, 2017)
- Applied Statistics (VLAG, Wageningen, The Netherlands, 2017)
- Reviewing a Scientific Paper (WGS, Wageningen, The Netherlands, 2017)
- Scientific Publishing (WGS, Wageningen, The Netherlands, 2017)
- Writing Grant Proposal 2 (WGS, Wageningen, The Netherlands, 2017)
- Exploring Teaching outside Academia: Orientation Reflection (WGS, Wageningen, The Netherlands, 2017)
- Supervising B.Sc. and M.Sc. students (WGS, Wageningen, The Netherlands, 2017)
- 8th Philosophy and ethic of Food Science and Technology (WGS, Wageningen, The Netherlands, 2018)
- WGS PhD Workshop Carousel (WGS, Wageningen, The Netherlands, 2018)

C: Assisting in teaching and supervision activities

- Supervising 2 BSc and 5 MSc theses (FQD, Wageningen, The Netherlands, 2017-2020)
- ELS 65700 The Art of Public Speaking(ELS, Wageningen, The Netherlands, 2019)
- HAP 11303 Presentation Skills (ELS, Wageningen, The Netherlands, 2019)
- FQD 21306 Food Packaging (FQD, Wageningen, The Netherlands, 2020-2021)

D: Optional activities

- VLAG PhD Research Proposal (FQD, Wageningen, The Netherlands, 2017-2018)
- Weekly Group Meetings (FQD, Wageningen, The Netherlands, 2017-2022)
- Women in Science Mentoring Workshop (PEER/USAID, Kigali, Rwanda, 2018)
- Reviewing Scientific Article: Journal of Functional Foods (Elsevier, The Netherlands, 2019)
- Seminar Series (CAFE, The University of Sydney, Australia, 2020-2022)
- CD4D2 Knowledge Transfer Programme (IOM, Den Haag, The Netherlands, 2021-2022)

*Poster presentation

**Oral presentation

CAFE: Center for Advance Food Engineering

CD4D2: Connecting Diaspora for Development 2

ELS: Education and Learning Sciences

EFFoST: European Federation of Food Science and Technology

FQD: Food Quality and Design

GHI: Global Harmonization Initiative

INREF: Interdisciplinary research and Education Fund

IOM: International Organization for Migration

NIFST: Nigerian Institute of Food Science and Technology

PEER: Partnerships for Enhanced Engagement in Research

USAID: United States Agency for International Development

VLAG: Advanced studies in Food Technology, Agrobiotechnology, Nutrition and Health Sciences

WIAS: Wageningen Institute of Animal Sciences

WGS: Wageningen Graduate School

WUR: Wageningen University and Research

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