Heliyon 11 (2025) e42249

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Inclusion of antimicrobial and antioxidant spices into milk candy towards enhancement of nutrient contents and bio-functional activities

Adeyanmola Oluwaseyi Faturoti, Clement Olusola Ogidi *

Department of Food Science and Technology, Olusegun Agagu University of Science and Technology, PMB 353 Okitipupa, Nigeria

ARTICLE INFO

Keywords:
Phytochemicals
Medicinal plants
Functional foods
Confectionary
Dairy products
Organoleptic
Lactose intolerance
Prebiotic
And lactic acid bacteria

ABSTRACT

Herbs and spices are known for their health benefits and thus, commonly used in foods to enhance taste, flavour and shelf life. This study produced milk candy with medicinal spices, assessed their proximate composition, prebiotic, and antioxidant activities using standard methods. Phenol contents of extracts from *Aframomum melegueta* (25.40 mg/100g) and *Ocimum gratissimum* (24.80 mg/100g) were not significantly different ($p \geq 0.05$). Extracts from *Ocimum gratissimum* (5.50 mg/100g), *Piper guineense* (5.50 mg/100g), *Cinnamomum burmannii* (5.10 mg/100g), and *Trigonella foenum-graecum* (5.20 mg/100g) have similar ($p \geq 0.05$) terpenoid content. Zones of inhibition displayed by the spices against indicator microorganisms ranged from 5.20 mm to 10.30 mm with MIC values of 50–200 μg/mL. Extracts from *Ocimum gratissimum*, *Aframomum melegueta*, and *Xylopia aethiopica* scavenged 1, 1-diphenyl-2-picrylhydrazyl (DPPH) with similar ($p \geq 0.05$) values of 90.6 %, 91.5 %, and 92.5 %, respectively. The crude fibre of milk candy with spices increased from 6.90 to 8.10 % when compared ($p \geq 0.05$) to milk candy without spices (3.90 %). Milk candies with *Xylopia aethiopica* and *Zingiber officinale* have the same scavenging activity of 65.80 % against DPPH. Milk candy fortified with *Cuminum cyminum* supported the growth of probiotics; *Lactobacillus fermentum* with the highest values of 8.30×10^5 cfu/mL and 6.90×10^5 cfu/mL for *Lactobacillus acidophilus*. Addition of spices to milk candy gain wide acceptance by consumers due to savory. Medicinal herbs and spices can be successfully incorporated into milk products to enhance their bio-functional potentials, and to alleviate the intolerance of individual that are allergic to dairy products.

1. Introduction

Functional foods are more valuable to human health and are able to reduce risks of chronic diseases due to the presence of bioactive component. Consumers are more interested in functional foods that are beneficial to their body in order to maintain a healthy lifestyle [1]. The understanding of consumer's choice, values, and importance of medicinal foods had increased the commercial feat of many functional foods, ultimately based on taste, appearance, price, health claims and appealing [2]. The major bioactive ingredients in functional foods are dietary fiber, carotenoids, fatty acids, phenolic acids, flavonoids, isothiocyanates, plant stanols and sterols, phytoestrogens, protein, vitamins, and minerals [3]. These phytochemicals are therapeutic in nature and adequately present in

* Corresponding author.
E-mail addresses: co.ogidi@oaustech.edu.ng, clementogidi@yahoo.com (C.O. Ogidi).

https://doi.org/10.1016/j.heliyon.2025.e42249
Received 1 August 2024; Received in revised form 17 January 2025; Accepted 23 January 2025
Available online 27 January 2025

medicinal herbs and spices. Therefore, fortification of milk and milk products with medicinal plants will provide wide putative functional dairy products with more nutritional values and to help reduce allergic to milk and milk products when consume by certain individuals [4].

Milk and other dairy products are widely consumed as functional food because of their adequate nutrients but certain people are allergenic to casein, α-lactalbumin, and β-lactoglobulin in milk [5]. Most adult people are lactose intolerant; unable to digest lactose completely with different symptoms like; bloating, diarrhea, and abdominal discomfort after consuming milk. Several technologies of milk processing such as glycation, heat treatment, enzymatic (protease) hydrolysis and fermentation by lactic acid bacteria have been adopted to partly minimize the allergens of milk products [6,7]. Notably, some of these of methods reduced the nutritional composition of the milk final products. Alternatively, incorporation of herbs and spices into milk and milk products can reduce the risk associated with consumption of final products and also improve dietary composition of dairy products [8]. The uses of herbs and spices in food preparation have been espoused on the basis of its traditional medicine, choice of individual, culture, religious background, knowledge, attitudes, beliefs and their availability. Medicinal spices such as *Aframomum melegueta*, *Xylopia aethiopica*, *Monodora myristica*, *Ocimum gratissimum*, *Zingiber officinale*, *Piper guineense* seed, *Syzygium aromaticum*, *Cinnamomum burmannii*, *Trigonella foenum-graecum*, *Cuminum cyminum*, and *Foeniculum vulgare* are remarkably use in food processing with wide potential applications as preservatives, colorants, and flavoring agent or food enhancers due to their pharmacological effects [9]. Beyond their culinary uses, these herbs and spices offer significant health benefits and their pharmacological properties make them valuable tools for promoting wellness, addressing chronic diseases and life-threatening conditions.

Recently, medicinal herbs and spices have been a major component of raw material in food and pharmaceutical industries due to their functional bioactive compounds [10]. In recent time, research has noticeably grown into assessing the health benefits of herbs and spices as potential alternative therapies to mitigate the risk of developing chronic diseases like arthritis, cardiovascular disease, neurodegenerative conditions, chronic inflammation, cancer, obesity, and diabetes [11,12]. Many of the positive health benefits of herbs and spices in ameliorating chronic diseases are achieved through the direct action of phytochemicals that target receptors or enzymes involved in various anti-inflammatory pathways or immune responses [13]. The underutilization of herbs and spices has been accredited to their intense and distinctive flavour profile, which encompasses bitterness, odour, and spicy pungent, fragrance and sour notes.

Herbs and spices possess a wide array of functional properties but their potent taste detest certain consumers and therefore, not adequately accepted by such consumers. This challenge has contributed to the limited uses of medicinal herbs and spices in various foods, despite their potential to enhance dishes with unique and medicinal benefits [14]. To make the uses of medicinal herbs and spices more appealing, palatable to consumers as well as to gain wide acceptance by those who are not accustomed to the pungent flavour, a coating or mixing of herbs and spices with sweet substances such as sugar, honey, milk is required to balance their intense taste, odour and sometimes overpowering flavour.

Incorporation of herbs and spices into milk and milk-based product can serve as an effective delivery source of functional foods to consumers, to address the issue of health challenges associated with consumption of milk and milk products, and to improve their marketing value [4]. Fortification of milk products with herbs and spices may not only enhance the flavour but release the bioactive ingredients accountable for antimicrobial and antioxidant in the herbs and spices into the final milk products [15]. A number of herbs and spices renowned for their potent antioxidant, antimicrobial, anti-inflammatory properties, and as flavouring agent to reduce the uses of chemical additives [10]. The addition of medicinal herbs and spices into milk and milk products may imparts a delightful aroma and create a harmonious blend of tastes to the final product. Hitherto, there is a few reports on the medicinal uses of herbs and spices in dairy industry. This study therefore, produced milk candy with medicinal herbs and spices, assessed their nutrient contents, organoleptic properties, antioxidant potentials and ability to support the probiotics growth.

2. Materials and methods

2.1. Reagents used

1,1-diphenyl-2-picrylhydrazyl (DPPH), ethanol, methanol, trichloroacetic acid, iron (II) sulphate, butylated hydroxytoluene (BHT) were products of Sigma-Aldrich (Steinheim, Germany). Hydrogen peroxide, deoxyribose, and thiobarbituric acid were from Amresco (Ohio, USA). Fructooligosaccharides, lanthanum chloride were purchased from Sigma-Aldrich Fine Chemicals (St. Louis, MO, USA).

2.2. Collection of spices and other materials

Aframomum melegueta (alligator pepper), *Ocimum gratissimum* L. (African basil leaves), *Syzygium aromaticum* L. (clove), *Cinnamomum burmannii* (cinnamon), *Monodora myristica* (calabash nutmeg), *Zingiber officinale* (ginger), *Piper guineense* (uziza seeds), *Xylopia aethiopica* (negro pepper), *Trigonella foenum-graecum* (fenugreek), *Cuminum cyminum* (cumin), and *Foeniculum vulgare* (fennel), powder milk, butter and sugar were sourced from Lagos and transported to Okitipupa, Nigeria.

2.3. Preparation of extracts from spices

The spices were sorted, cleaned and air dried at 29±2 °C for 7 days. Dried herbs and spices were pulverized into fine powder using kitchen electric grinder (70–300 mesh, Raylux, China) and stored in air tight container. Spices (100 g) each, were soaked in 1 L of 95 % (v/v) ethanol and for 48 h with slight shaking at intervals. Thereafter, the solution was filtered with Whatman filter paper Grade 1. The filtrates obtained were concentrated using a rotary evaporator (RE-52A, UNION Laboratories, England), and lyophilized in a freeze dryer (FD-10-MR, Xiangtan Xiangyi instrument Ltd, China) at −65 °C at 0.06 mbar.

2.4. Quantitative determination of phytochemicals in spices

The extracts from spices were screened qualitatively and quantitatively for phenol, flavonoid, alkaloids, terpenoids, steroids, and saponins, using standard methods described by Sofowora [16], Trease and Evans [17].

2.5. Antimicrobial activity of spices

The indicator microorganisms namely; *Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae, Salmonella typhi,* and *Candida albicans* were isolated from ready-to –eat foods like meat-pie, egg rolls, rice, and beans using the methods described in Ogidi et al. [18]. The cultural characteristics, and biochemical tests on microorganisms were carried out using standard microbiological methods described by Cheesbrough [19]. The identity of microorganisms were confirmed by using Cowan and Steel [20]. The antimicrobial activity of spices was determined using the agar well diffusion methods described by Cheesbrough [19]. Briefly, the indicator microorganisms were sub-cultured into their respective growth media; nutrient broth for bacteria and yeast extract broth for *Candida albicans*. The test tubes were incubated at 37 °C for 24 h for bacteria, while tube with yeast was incubated at 28 °C for 48 h. The inoculum size was adjusted to 0.5 McFarland turbidity standards. A sterile cotton swab was used aseptically to transfer organism onto the dried surface of sterile Mueller Hinton Agar plate. A sterile cork borer was used to create wells with a diameter of 4 mm. The spices extracts were sterilized using a Millipore filter (0.22 μm) before being introduced into the wells in the Petri dishes that had already been inoculated with indicator microorganisms.

2.6. Antioxidant activities of herbs, spices and produced milk candy

2.6.1. 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging assay

DPPH free radical assays was performed according to method described by Gyamfi et al. [21] with slight modifications. Briefly, reaction mixture of 100 μL of the extract in 0.1 M DPPH solution was prepared. After that, the resulting solution in test tubes were vortexed, and incubated in the dark for 30 min. After which, the absorbance was determined at 517 nm. The control contained only DPPH solution in methanol instead of sample, while methanol served as the blank. This method was adopted to determine the DPPH radical scavenging of the spiced-milk candy.

Percentage DPPH radical inhibition was calculated as follows:

Scavenging activity (%) = {(A control –A sample)/A control} x 100%

2.6.2. Hydroxyl radical scavenging assay

The potential of spices extracts and milk candy to prevent Fe^{2+}/H_2O_2 induced decomposition of deoxyribose was carried out using the method described by Halliwell et al. [22]. Briefly, the reaction mixture contained spice extract (100 μL), 120 μL of 20 mM deoxyribose, 400 μL of 0.1 M phosphate buffer (pH 7.4), 40 μL of 500 μM $FeSO_4$, 100 mM EDTA solution, 40 μL of 20 mM hydrogen peroxide, ascorbic acid (100 μM) and made up to 800 μL total volume with distilled water. After incubating the solution for 30 min at 37 °C, 0.5 mL of 2.8 % trichloroacetic acid was added, followed by addition of 0.4 mL of 0.6 % thiobarbituric acid solution. The mixture was placed in boiling water for 15 min. After cooling, the absorbance was measured at 532 nm in a spectrophotometer. This method was adopted to determine the hydroxyl radical scavenging of the spiced-milk candy.

The percentage hydroxyl radical scavenging activity was calculated as follows:

Scavenging activity (%) = {(A control –A sample)/A control} x 100%

2.6.3. Iron chelation activity

The Fe^{2+} chelating activity of extract from spices against iron (II) sulphate ($FeSO_4$) was determined using the methods described by Puntel et al. [23] with little modification. Briefly, 150 mM FeSO4 was added to a reaction mixture containing 168 μl of 0.1M Tris-HCl pH 7.4, 218 μl saline (0.9 % NaCl) and extract (100 μl) concentrations of 100 and 200 μg/mL. Thereafter, the mixture was incubated at 27 °C for 5min, before the addition of 13 μl of 0.25 % 1, 10-phenantroline (w/v). The absorbance was subsequently measured at 510 nm. This method was adopted to determine the chelating effect of the spiced-milk candy.

Chelating activity of the spices on iron radical was calculated using this equation:

Scavenging activity (%) = {(A control –A sample)/A control} x 100%

2.7. Production of milk candy with spices

Milk candy were produced by heating the ratio of sugar, butter and water (1: 2: 4, wt: wt: v) at 80°C–90 °C. During the heating, the mixture was constantly stirred using a sterile wooden spatula in a non-stick heating pan for 2–3 min until it melted properly. Thereafter, the mixture was allowed to cool down to 50 °C, milk and spices (2: 1 wt: wt) with 0.2 g of citric acid were added, stirred simultaneously to ensure equal distribution and to avoid lumps. The mixture was poured into a sterile tray containing parchment paper and allowed to cool at room temperature for 10−20 min. The spiced-milk candy was cut into desired shape (Fig. 1a–l) and store in an airtight container for further study.

2.8. Organoleptic properties of spiced-milk candy

Organoleptic properties were carried out on the spiced-milk candy by trained thirty panelists. The judges scored the samples for colour, taste (sweet, bitter, sour and salty), texture, characteristics flavour and overall acceptability using a 9-point hedonic scale ranging from 1 = dislike extremely and 9 = like extremely.

2.9. Proximate composition analysis of spiced-milk candy

Proximate composition (moisture content, ash, crude fiber, fat, crude proteins and carbohydrates contents) of spiced-milk candy were determined using the standard methods of Association of Official Analytical Chemists [24]. Total carbohydrates was determined by difference as follows: Carbohydrates (%) = 100 - (% moisture + % fat + % ash + % crude fiber + % crude protein).

2.10. Determination of mineral contents of spiced-milk candy

The samples were ashed in a muffle furnace for 5 h at 600 °C. The ash (2.0 g) was digested in 5 mL of HCl and 2 mL of 5 % v/v lanthanum chloride. The mixture was boiled, filtered and made up to standard volume with deionized water. Atomic Absorption Spectrometer (Buck Scientific, Model 200, Inc. East Norwalk, Connecticut, USA) was used at the appropriate wavelength to determine minerals; Zn, Fe, Ca, and P. Flame photometer (Jenway PFP 7, Staffordshire, UK) was used to determine Na and K contents. Mineral standard solution at 1000 μg/mL in 1 % v/v HNO_3 was used for the calibration of atomic absorption spectroscopy.

Fig. 1. (a–l): Milk candy (a) without spice, with spice (b) *Ocimum gratissimum*, (c) *Monodora myristica*, (d) *Zingiber officinale,* (e) *Piper guineense*, (f) *Aframomum melegueta*, (g) *Xylopia aethiopica*, (h *Syzygium aromaticum*, (i) *Cinnamomum burmannii*, (j) *Trigonella foenum-graecum* (k) *Cuminum cyminum*, and (l) *Foeniculum vulgare.*

2.11. Prebiotic activity of the spiced-milk candy

Two probiotic strains; *Lactobacillus fermentum* and *Lactobacillus acidophilus* were isolated from fermented maize (Ogi) and their probiotic activity were confirmed using methods of Jose et al. [25]. The growth rate of Lactic acid bacteria in the presence of spiced-milk candy was determined using the method described by Ogidi et al. [26] with little modifications. Briefly, 10.0 mL of de Man, Rogosa and Sharpe (MRS) broth in test tubes were sterilized at 121 °C for 15 min and then allowed to cool. Spiced-milk candy; 0.5 g was exposed to UV light for 15 min and later added into MRS broth. The test tubes were inoculated with 100 μL of 10^6 colony forming units (CFU) of *Lactobacillus fermentum* and *Lactobacillus acidophilus*. Test tube containing MRS broth without any milk candy served as the negative control. Test tubes with MRS broth and 0.5 g of glucose or fructose oligosaccharides (FOS) serve as positive controls. The test tubes were incubated at 37 °C for 48 h under anaerobic conditions. After incubation, growth rate of the two probiotics was quantified by measuring their optical cell density using UV spectrophotometer at 620 nm. Thereafter, 100 μl of 10^{-4} dilution factor of *Lactobacillus fermentum* and *Lactobacillus acidophilus* was transferred to MRS agar. Petri dishes were incubated at 37 °C for 48 h, bacteria colonies were counted and reported in colony forming unit per milliliter (CFU/mL).

2.12. Statistical analysis

Data obtained from the experiment were subjected to one-way Analysis of Variance (ANOVA) using SPSS Statistics version 22. Mean values and standard deviations were calculated for triplicate analyses. The differences between means were compared using the New Duncan Multiple Range Test at a significance level of $p \leq 0.05$.

3. Results and discussion

3.1. Phytochemical constituents of extracts from spices

The phytochemical constituents of extracts from spices are presented in Table 1. Phytochemical in spice with respect to phenol content within 9.50–25.40 mg/100g, flavonoid ranging from 6.90 to 11.10 mg/100g, alkaloid is 5.20–13.10 mg/100g and terpenoid is 3.00–5.50 mg/100g. Phytochemicals are biologically active, naturally occurring chemical compounds found in plants and offered potential therapeutic benefits beyond attributed macronutrients and micronutrients [27]. The phenol content in extracts from *Aframomum melegueta* (25.40 mg/100g) and *Ocimum gratissimum* (24.80 mg/100g) were not significantly different ($p \geq 0.05$). Phytochemicals such as phenol, saponin, alkaloids, flavonoids, terpenoids, cardiac glycoside, and tannins are considered secondary metabolites in plants responsible for antioxidant properties, antimicrobial activities, enzyme detoxification regulation, immune system modulation, hormone metabolism, and anticancer property [28]. The traditional uses of *Syzygium aromaticum* as food preservation and other various pharmacological activities has been connected to its rich phytochemicals [29]. Findings of Rather et al. [30] revealed the presence of phenols, phenolic glycosides, and volatile aroma compounds such as transanethole, estragole, and fenchone as the major bioactive constituents of *Foeniculum vulgare*. The finding of Ogwu et al. [31] revealed that the medicinal properties of different herbs and spices with distinctive aroma or fragrance attributed to presence of various phytochemical constituents, which include phenols, myristicin, limonene, beta-fatty acids, flavonoids, caryophyllene, pinene, terpenoids, tannins, steroids, glycosides, carotenoids, alkaloids, vitamins, and minerals. The presence of these bioactive compounds in aromatic spices and herbs contributed to their ethnomedicinal uses as better alternative choice that can be incorporated into food products.

3.2. Antimicrobial and antioxidants potentials of the extracts from spices

Table 2 shows the zones of inhibition exhibited by the extracts from spices against tested microorganisms. Extract from *Aframomum*

Table 1
Phytochemical constituents (mg/100g) of extracts from spices.

Extracts	Phenol	Flavonoid	Steroid	Terpenoid	Saponin	Alkaloid
AP	25.40 ± 1.60^{a}	10.40 ± 0.20^{a}	0.70 ± 0.00^{c}	4.80 ± 0.20^{b}	0.40 ± 0.00^{c}	8.50 ± 0.10^{c}
NP	21.10 ± 0.70^{b}	8.60 ± 0.10^{c}	0.90 ± 0.00^{c}	3.00 ± 0.01^{de}	0.70 ± 0.00^{b}	6.90 ± 0.01^{d}
CN	17.70 ± 0.51^{c}	7.80 ± 0.20^{d}	1.30 ± 0.00^{b}	3.10 ± 0.00^{de}	0.40 ± 0.00^{c}	9.40 ± 0.70^{c}
AB	24.80 ± 1.40^{a}	10.30 ± 0.50^{a}	1.80 ± 0.01^{a}	5.50 ± 0.10^{a}	0.70 ± 0.00^{b}	8.90 ± 0.12^{c}
GG	21.90 ± 0.21^{b}	7.70 ± 0.40^{d}	0.80 ± 0.00^{c}	3.80 ± 0.06^{d}	0.70 ± 0.00^{b}	11.10 ± 0.00^{b}
UU	9.60 ± 0.21^{e}	5.80 ± 0.20^{f}	1.40 ± 0.00^{b}	5.50 ± 0.15^{a}	0.50 ± 0.00^{c}	5.50 ± 0.07^{e}
CC	21.00 ± 2.40^{b}	6.90 ± 0.21^{e}	1.30 ± 0.01^{b}	3.90 ± 0.10^{d}	0.40 ± 0.01^{c}	13.10 ± 0.60^{a}
CI	17.10 ± 1.30^{c}	9.80 ± 0.30^{b}	0.50 ± 0.00^{d}	5.10 ± 0.00^{a}	0.40 ± 0.00^{c}	12.80 ± 0.20^{a}
FE	11.20 ± 0.33^{d}	6.60 ± 0.00^{e}	0.70 ± 0.00^{c}	5.20 ± 0.00^{a}	1.10 ± 0.00^{a}	5.70 ± 0.00^{e}
CU	9.50 ± 0.02^{e}	5.80 ± 0.01^{f}	0.80 ± 0.00^{c}	4.60 ± 0.00^{c}	0.90 ± 0.00^{a}	7.05 ± 0.00^{d}
FN	10.60 ± 0.11^{d}	5.70 ± 0.00^{f}	0.60 ± 0.00^{d}	4.40 ± 0.00^{c}	0.90 ± 0.00^{a}	6.10 ± 0.00^{e}

Values within the same column sharing the same alphabet are not significantly different ($p \geq 0.05$).
Key: Extract from AP: *Aframomum melegueta*, NP: *Xylopia aethiopica*, CN: *Monodora myristica*, AB: *Ocimum gratissimum*, GG: *Zingiber officinale*, UU: *Piper guineense* seed, CC: *Syzygium aromaticum*, CI: *Cinnamomum burmannii*, FE: *Trigonella foenum-graecum*, CU *Cuminum cyminum*, and FN: *Foeniculum vulgare*.

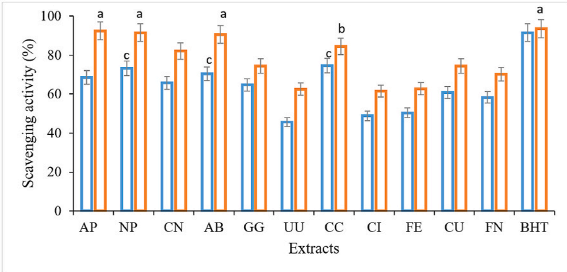
Table 2
Zones of inhibition (mm) at 100 μg/mL, MIC (μg/ml) and MBC (μg/ml) of extract against indicator microorganisms.

Extracts	*S. aureus*	*Klebsiella pneumoniae*	*E. coli*	*Salmonella typhi*	*Candida albicans*	MIC	MBC
AP	9.00 ± 0.00^{b}	10.30 ± 0.20^{a}	9.30 ± 0.40^{b}	7.50 ± 0.00^{c}	8.00 ± 0.00^{c}	50–200	50 – ≥ 200
NP	6.50 ± 0.02^{d}	8.00 ± 0.01^{b}	6.60 ± 0.00^{e}	6.80 ± 0.00^{cd}	9.10 ± 0.03^{b}	50–150	100–200
CN	8.00 ± 0.00^{b}	7.50 ± 0.00^{c}	7.20 ± 0.00^{d}	9.10 ± 0.11^{b}	8.00 ± 0.01^{c}	50–150	100 – ≥ 200
AB	7.30 ± 0.01^{c}	6.70 ± 0.00^{cd}	7.80 ± 0.00^{cd}	6.80 ± 0.02^{cd}	7.80 ± 0.01^{c}	50–200	100–200
GG	7.60 ± 0.00^{c}	8.20 ± 0.10^{b}	8.20 ± 0.10^{c}	8.80 ± 0.10^{b}	8.00 ± 0.00^{c}	50–150	100–200
UU	5.40 ± 0.00^{e}	7.40 ± 0.00^{bc}	6.60 ± 0.02^{e}	7.60 ± 0.07^{c}	8.80 ± 0.00^{bc}	50–200	50 – ≥ 200
CC	7.40 ± 0.00^{c}	8.20 ± 0.30^{b}	7.10 ± 0.01^{d}	9.30 ± 0.03^{b}	9.00 ± 0.00^{b}	50–200	50–200
CI	8.10 ± 0.02^{b}	7.60 ± 0.11^{bc}	7.10 ± 0.01^{d}	7.50 ± 0.01^{c}	6.50 ± 0.01^{d}	50–150	100 – ≥ 200
FE	5.50 ± 0.00^{e}	6.10 ± 0.00^{d}	0.0	6.20 ± 0.00^{d}	6.00 ± 0.00^{d}	100–150	100 – ≥ 200
CU	5.20 ± 0.00^{e}	5.80 ± 0.00^{d}	0.0	0.0	7.50 ± 0.00^{cd}	100–200	100 – ≥ 200
FN	6.10 ± 0.00^{d}	5.80 ± 0.00^{d}	6.60 ± 0.00^{e}	5.80 ± 0.00^{d}	6.40 ± 0.00^{d}	50–150	100 – ≥ 200
GT	11.0 ± 0.10^{a}	10.40 ± 0.22^{a}	11.30 ± 0.30^{a}	10.10 ± 0.31^{a}	ND	ND	ND
KT	ND	ND	ND	ND	11.90 ± 0.70^{a}	ND	ND

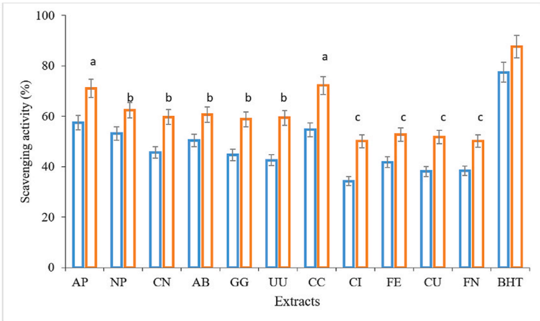
Values within the same column sharing the same alphabet are not significantly different ($p \geq 0.05$).
Keys: Extract from AP: *Aframomum melegueta*, NP: *Xylopia aethiopica*, CN: *Monodora myristica*, AB: *Ocimum gratissimum*, GG: *Zingiber officinale*, UU: *Piper guineense* seed, CC: *Syzygium aromaticum*, CI: *Cinnamomum burmannii*, FE: *Trigonella foenum-graecum*, CU *Cuminum cyminum*, FN: *Foeniculum vulgare*, GT: gentamycin and KT: ketoconazole, 0.0: no inhibition at 200 μg/mL (MIC and MBC >200 μg/mL), ND: not detected.

melegueta had the highest inhibited zone of 10.30 mm against *Klebsiella pneumoniae* and similar ($p \leq 0.05$) to the inhibitory activity (10.40 mm) of gentamycin against *Klebsiella pneumoniae.* Findings of Olajuyigbe et al. [32] revealed that *Aframomum melegueta* displayed antibacterial activity against the different multidrug-resistant bacteria of clinical importance such as *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Aeromonas hydrophila*, *Pseudomonas aeruginosa*, and *Plesiomonas shigelloides* with inhibition zones ranging between 12.0 mm and 14.0 mm. *Syzygium aromaticum* inhibited the growth *of Salmonella* Typhi with zone of inhibition of 9.30 mm. Findings of Kiralan and Ketenoglu [33] revealed the antimicrobial activity of clove extracts against selected food spoilage microorganisms such as *Bacillus subtilis, Staphylococcus*. *Syzygium aromaticum* is used as a natural, non-harmful preservative, flavoring additive in food products due to its antimicrobial, antioxidant, and preservative properties [34]. Extract from *Xylopia aethiopica* inhibited *Candida albicans* with *zones of inhibition* 9.40 mm. *Xylopia aethiopica* is rich in diverse phytonutrients with antimicrobial potential and can be a very good alternative source of food [35]. The extracts of *O. gratissimum* inhibited the growth of, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *E. coli*, and *Bacillus cereus* [36]. The findings of Batiha et al. [37] revealed that *S. aromaticum* inhibited various actions of pathogens like Theileria, Plasmodium, Babesia, Herpes simplex, and hepatitis C viruses. Phyto-constituents detected in the extract of *Syzygium aromaticum* was responsible for the antioxidant and antimicrobial activities [38]. Antimicrobial properties of herbs and spices demonstrate their potential uses in milk and dairy product as they effectively regulated the proliferation of spoilage and pathogenic microorganisms. The studied extracts from the herbs and spices inhibited gram negative, gram positive bacteria and yeast. The extracts from spices possessed MIC of 50–200 μg/mL, while MBC was within 50–200 μg/mL. Okechukwu et al. [39] revealed the antibacterial efficacy of essential oil from *M. myristica* against *Staphylococcus aureus* ATCC 27840 and *Escherichia coli* 0157 at concentration of 50–75 μg/mL. Ethanolic extracts of *Cuminum cyminum, Punica granatum*, *Syzygium aromaticum*, *Thymus vulgaris*, and *Zingiber officinales* were potentially effective with bacteriostatic and bactericidal activities against foodborne pathogenic bacteria with MIC values of 2.5–5.0 mg/mL and MBC of 5.0 and 12.5 mg/mL [40]. Medicinal spices possessed significant antibacterial, and antifungal activities and, making them a promising source for the development of novel and safe antimicrobial agents. Natural antimicrobial agents are currently needed in food industry to inhibit spoilage-causing microorganisms, to extend the shelf-life and increase the safety of food products [41].

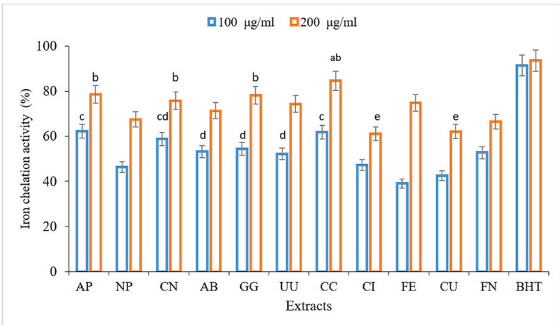
The scavenging activities of extracts from *Aframomum melegueta* (91.5 %), *Xylopia aethiopica* (92.5 %), *Ocimum gratissimum* (90.6 %) and BTH (93.6 %) against DPPH are not significantly different ($p \leq 0.05$) at 200 μg/mL (Fig. 2a–c). The values of 82.1 and 84.4 %, respectively obtained for DPPH scavenging activity of *Monodora myristica* and *Syzygium aromaticum* extracts are similar ($p \leq 0.05$). *Zingiber officinale* and *Cuminum cyminum* also have similar scavenging activity of 74.3 and 74.4 % against DPPH. Extracts from *Syzygium aromaticum* have the highest chelating effect of 84.6 % against Fe. Iron chelating effect of *Zingiber officinale* (78.30 %) and *Aframomum melegueta* (78.60 %) were not significantly different ($p \leq 0.05$). *Monodora myristica*, *Trigonella foenum-graecum*, and *Piper guineense* displayed similar ($p \leq 0.05$) chelating effect of 75.80 %, 74.90 %, and 74.40 % against Fe. *Monodora myristica* demonstrated antioxidant capacity against 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging, ferric reducing power, and total antioxidant capacity in studies of Okechukwu et al. [39]. *Trigonella foenum-graecum* shows a good antioxidant activity. The antioxidant and biological activities of *Trigonella foenum-graecum* attributed to the presence of palmitic acid and phytol as detected by GC-MS analysis [42]. Linoleic acid, α-linolenic acid, sterols, tocopherols, and fatty acids are the bioactive constituents of fenugreek seeds, which contribute to its potential applications in the food and pharmaceutical industries [43]. Quercetin, quercitrin, rutin, ellagic acid, chlorogenic acid, caffeic acid, and isoquercitrin are the phenolic compounds in the extracts of *Ocimum* spp, *Xylopia aethiopica*, and *Piper guineensis*, which are the major compounds responsible for antioxidant properties [44,45]. The consumption of aromatic herbs and spices play a very significant role in defence against oxidative reactions and microbial infections, and thus, possessing better activities over synthetic drugs.



(a)



(b)



(c)

Fig. 2. (a–c): Antioxidant activities of extracts from herbs and spices against (a) DPPH, (b) OH^-, and (c) Fe at 100 µg/mL and 200 µg/mL Scavenging activity against DPPH, OH and Fe with similar alphabet were not significantly different from each other at $p \leq 0.05$. Error bars in the figure represent standard deviations (SD).

Keys: Extract from AP: *Aframomum melegueta*, NP: *Xylopia aethiopica*, CN: *Monodora myristica*, AB: *Ocimum gratissimum*, GG: *Zingiber officinale*, UU: *Piper guineense* seed, CC: *Syzygium aromaticum*, CI: *Cinnamomum burmannii*, FE: *Trigonella foenum-graecum,* CU *Cuminum cyminum*, FN: *Foeniculum vulgare,* and BHT: butylated hydroxytoluene.

3.3. Organoleptic properties of spiced milk candy

The organoleptic properties of spiced milk candies are presented in Table 3. The sensory scores showed that all the spiced-milk candies were accepted by the panelists. Addition of spices into milk candy contributed to the colour (Fig. 1a–l) and appealed to consumers appreciated to the fragrance, tatse and savoury of spices in the candy. The findings is similar to Shukla and Kandra [46]. The researchers attributed the consumer acceptance of 'Nutra' candy, in terms of flavour, colour, and texture to the addition of *Sesamum indicum* seeds and *Phoenix dactylifera*. The findings of Kailey et al. [47] revealed that consumer accepted candy produced with *Foeniculum vulgare*. The wide acceptance of spiced-milk candy by consumers establish that vital component of the spices has been effectively absorbed into milk candy, thereby contributing to its flavour as well as increasing its palatability.

Table 3
Organoleptic properties of spiced milk candy.

Samples	Colour	Taste	Aroma	Texture	Mouth feel	flavour	General acceptability
CCT	8.00 ± 0.00^{a}	6.20 ± 0.00 ^{bc}	6.70 ± 0.03^{c}	6.70 ± 0.01^{c}	7.00 ± 0.03^{b}	6.10 ± 0.00^{c}	6.70 ± 0.03^{b}
CAP	7.70 ± 0.03^{a}	6.70 ± 0.00^{b}	7.00 ± 0.02^{b}	7.70 ± 0.03^{b}	7.00 ± 0.01^{b}	8.00 ± 1.00^{a}	7.60 ± 0.03^{a}
CNP	7.70 ± 0.01^{a}	7.00 ± 0.00^{a}	7.70 ± 0.05^{a}	8.70 ± 0.03^{a}	7.20 ± 0.01^{b}	8.00 ± 0.30^{a}	7.60 ± 0.00^{a}
CCN	7.20 ± 0.04^{b}	6.20 ± 0.00^{b}	7.00 ± 0.01^{b}	6.00 ± 0.01 ^{d}	7.00 ± 0.00^{b}	7.80 ± 0.00^{a}	7.40 ± 0.10^{a}
CAB	7.30 ± 0.01^{b}	6.20 ± 0.00^{b}	6.70 ± 0.00^{c}	6.60 ± 0.00^{c}	7.00 ± 0.20^{b}	7.50 ± 0.01^{b}	7.50 ± 0.00^{a}
CGG	7.00 ± 0.02^{c}	7.00 ± 0.01^{a}	7.25 ± 0.00^{b}	6.25 ± 0.00^{d}	7.00 ± 0.01^{b}	8.00 ± 0.03^{a}	7.50 ± 0.00^{a}
CUU	6.75 ± 0.00^{c}	6.75 ± 0.01^{b}	6.80 ± 0.01^{c}	6.25 ± 0.03 ^{d}	6.70 ± 0.21^{c}	7.80 ± 0.01^{a}	7.70 ± 0.10^{a}
CCC	7.40 ± 0.00^{b}	7.20 ± 0.00^{a}	6.70 ± 0.05^{c}	7.50 ± 0.03^{b}	6.80 ± 0.17^{c}	7.90 ± 0.09^{a}	7.70 ± 0.00^{a}
CCI	6.50 ± 0.60^{c}	6.30 ± 0.00^{b}	6.70 ± 0.03^{c}	6.50 ± 0.00^{c}	6.50 ± 0.00^{c}	7.50 ± 0.05^{b}	7.50 ± 0.03^{a}
CFE	7.50 ± 0.40^{b}	6.80 ± 0.01^{b}	7.70 ± 0.00^{a}	8.70 ± 0.02^{a}	7.60 ± 0.20^{a}	8.00 ± 0.00^{a}	7.70 ± 0.01^{a}
CCU	6.80 ± 0.11^{c}	6.50 ± 0.00^{b}	7.00 ± 0.00^{b}	6.70 ± 0.01^{c}	7.50 ± 0.03^{a}	7.80 ± 0.00^{a}	7.50 ± 0.05^{a}
CFN	7.20 ± 0.37^{b}	6.60 ± 0.00^{b}	8.20 ± 0.00^{a}	7.60 ± 0.10^{b}	7.50 ± 0.03^{a}	7.80 ± 0.01^{a}	7.40 ± 0.00^{a}

Values within the same column sharing the same alphabet are not significantly different ($p \geq 0.05$).
Key: CCT: milk candy without spices, milk candy with CAP: *Aframomum melegueta*, CNP: *Xylopia aethiopica*, CCN: *Monodora myristica*, CAB: *Ocimum gratissimum*, CGG: *Zingiber officinale* powder, CUU: *Piper guineense* seed, CCC: *Syzygium aromaticum*, CCI: *Cinnamomum burmannii*, CFE: *Trigonella foenum-graecum*, CCU: *Cuminum cyminum*, and CFN: *Foeniculum vulgare*.

3.4. Proximate composition of spiced milk candy

Table 4 shows the proximate composition of spiced-milk candy and milk candy without spices. The moisture content of non-spiced milk candy was the highest ($p \leq 0.05$) as 10.90 %. High moisture content of food products support the growth of bacteria, yeasts, mold and expose it to early spoilage. The findings of Acuff et al. [48] revealed that food samples with relatively high moisture content are more susceptible to microbial invasion over time if not properly stored. The inclusion of spices in the milk candy reduced their moisture content with values ranging from 6.50 to 7.60 %. The lower moisture content of spiced milk candy is an indication that the lower water activity will hinder the growth of certain microorganisms. Moisture content of food serve as an index of its water activity, a parameter of significant importance in assessing the stability and microbial spoilage potential of food products [49]. The final water content of food product significantly influences its texture and shelf life. Water activity or the relative vapor pressure of water in the confection is an important parameter often used to describe microbial stability, texture, shelf life and water migration during storage [50]. Milk candy fortified with spices entrust their candy with longer shelf life, and limit deterioration in terms of quality or taste due to inability of microbial colonization or activities [51]. Hence, aromatic herbs and spices can serve as natural preservatives in food. Crude fibre content was higher in the functional and spiced-milk candy with value ranged from 6.90 to 8.10 %, while the milk candy without spices has the lowest value of 3.90 %. The addition of spices contributed to an increase in the crude fiber content of the spiced-milk candy. Crude fibre has physiological effects on the gastrointestinal tract, sterol metabolism and stool weight and thus, helps to maintain or stabilise human health and to reduce cholesterol of the body [52]. Food with lower crude fibre is undesirable and has been associated with constipation, heart diseases, phlebitis, obesity, cancer of the colon, and diabetes. Crude fibre adds bulk to food, reduces the intake of excess starchy food and hence, guards against metabolic condition such as hypertension and diabetes mellitus [53]. The incorporation of herbs and spices into milk candy will reduce metabolic digestive disorders such as constipation and irritable bowel associated deficiency of crude fibre in foods.

Addition of herbs and spices into milk candy did not reduce the protein content (9.50–10.10 %). This indicates that incorporating herbs or spices into milk candy make the protein available for consumers. Protein is a macronutrient that is essential for muscle

Table 4
Proximate composition (%) of milk candy produced with medicinal spices.

Samples	Moisture	Fat	Crude fibre	Protein	Ash	Carbohydrates
CCT	10.90 ± 0.15^{a}	8.10 ± 0.02^{a}	3.90 ± 0.05^{d}	9.60 ± 0.06^{b}	0.93 ± 0.06^{c}	65.80 ± 0.23^{d}
CAP	6.50 ± 0.26^{c}	6.20 ± 0.06^{b}	7.60 ± 0.12^{b}	9.80 ± 0.12^{a}	1.30 ± 0.06^{a}	68.20 ± 0.12^{b}
CNP	7.60 ± 0.21^{b}	5.50 ±0.15^{d}	7.90 ± 0.20^{a}	9.60 ± 0.10^{b}	1.15 ± 0.01^{b}	68.25 ± 0.47^{b}
CCN	6.20 ± 0.12^{c}	5.90 ± 0.21^{c}	7.10 ± 0.01^{c}	10.10 ± 0.41^{a}	1.20 ± 0.01^{b}	69.50 ± 0.13^{a}
CAB	6.50 ± 0.26^{c}	6.00 ± 0.15^{c}	7.90 ± 0.12^{a}	9.50 ± 0.15^{b}	1.45 ± 0.01^{a}	68.65 ± 1.01^{b}
CGG	6.90 ± 0.12 ^{bc}	6.10 ± 0.15^{bc}	8.10 ± 0.15^{a}	10.00 ± 0.05^{a}	1.45 ± 0.00^{a}	67.45 ± 0.16^{c}
CUU	7.00 ± 0.15 ^{bc}	6.20 ± 0.12^{b}	7.40 ± 0.00^{b}	10.00 ± 0.20^{a}	1.20 ± 0.00^{b}	68.10 ± 0.23^{b}
CCC	7.30 ± 0.15^{b}	6.30 ± 0.06^{b}	7.70 ± 0.15^{b}	9.50 ± 0.15^{b}	1.60 ± 0.00^{a}	67.60 ± 0.31^{c}
CCI	7.30 ± 0.20^{b}	5.90 ± 0.23^{c}	7.60 ± 0.26^{b}	9.80 ± 0.04^{a}	1.20 ± 0.00^{b}	68.60 ± 0.60^{a}
CFE	7.45 ± 0.10^{b}	6.00 ± 0.00^{c}	8.00 ± 0.03^{a}	10.00 ± 0.12^{a}	1.10 ± 0.00^{b}	67.35 ± 0.90^{c}
CCU	6.80 ± 0.03 ^{bc}	6.10 ± 0.00^{bc}	7.60 ± 0.03^{b}	9.80 ± 0.02^{a}	1.10 ± 0.00^{b}	68.60 ± 1.05^{a}
CFN	7.10 ± 0.00 ^{bc}	6.00 ± 0.02^{c}	6.90 ± 0.03^{c}	9.90 ± 0.11^{a}	1.30 ± 0.00^{a}	68.80 ± 2.07^{a}

Values within the same column having the same alphabet are not significantly different ($p \geq 0.05$).
Key: CCT: milk candy without spices, milk candy with CAP: *Aframomum melegueta*, CNP: *Xylopia aethiopica*, CCN: *Monodora myristica*, CAB: *Ocimum gratissimum*, CGG: *Zingiber officinale* powder, CUU: *Piper guineense* seed, CCC: *Syzygium aromaticum*, CCI: *Cinnamomum burmannii*, CFE: *Trigonella foenum-graecum*, CCU: *Cuminum cyminum*, and CFN: *Foeniculum vulgare*.

growth, repair and various metabolic functions [54]. There was increase in the ash content from 0.93 % to 1.60 %, which could be attributed to the inclusion of spices into milk candy. The ash content in this present study is in accordance with the findings of Dhawan et al. [55], the researcher reported increased in ash content of matcha-based hard candy due to the presence of ginger (*Zingiber officinale*), cinnamon (*Cinnamomum zeylanicum* and *Cinnamon cassia*), and holy basil (*Ocimum sanctum*). The increase in ash content could be from availability of micro and macro-element in herbs and spices that are essential for various metabolic functions [56]. The fat content of milk candy without spices (9.08 %) was found to be the highest when compared ($p \leq 0.05$) to others with values ranging from 5.50 to 6.20 %. Confections without herbs or spices are often high in sugar and fat, which can contribute to their rejection by adults and immunocompromised individuals due to their health concerns. Addition of spices into milk candy decrease their fat content. Inclusion of basil, bay leaf, black pepper, cinnamon, coriander, cumin, ginger, oregano, red pepper, parsley, rosemary, thyme, and turmeric into foods have been suggested to be highly essential in suppressing the negative effects of cholesterol, overweight or obesity, reduce postprandial inflammation and concurrently attenuate chronic low-grade inflammation [57]. The carbohydrates content of spiced-milk candy ranged from 67.35 % to 69.50 %. The carbohydrates content of 89.41 %–91.41 % was obtained in the study of Dhawan et al. [55].

3.5. Mineral composition of spiced-milk candy

Table 5 shows the mineral composition of non-spiced and spiced milk candy. Inclusion of spices to enrich the milk candy increase the macro and micro minerals needed for the body and thus, making spiced-milk candy a healthy food for man. Milk candy fortified with spices stood out for their high levels of essential minerals particularly potassium, iron, zinc, phosphorus and calcium. Potassium content of spiced-milk candy ranging from 215.10 to 432.50 mg/100g, while the milk candy without spice had 73.30 mg/100g. Potassium is essential for maintaining proper nerve and muscle function, as well as regulating blood pressure. It is noteworthy that potassium-rich foods are often recommended for individuals with hypertension or those at risk of cardiovascular diseases [58]. The iron content of spiced-milk candy is within 76.30 mg/100g to 142.40 mg/100g with the highest value obtained in milk candy produced with *Xylopia aethiopica*. Milk candy fortified with *Aframomum melegueta* had the highest zinc of 133.60 mg/100g, followed by milk candies with *Piper guineense* (105.60 mg/100g) and *Ocimum gratissimum* (101.80 mg/100g). Zinc is widely distributed in medicinal plants and can be incorporated into man's foods as better alternative source. Zinc is a trace element in diabetes as co-factors for insulin and its deficiency symptoms include hypogonadism, growth failure, impaired wound healing, and decreased taste and smell acuity [59]. However, the availability of zinc in spiced-milk candy will aid in the prevention of its deficiency symptoms and associated diseases. The addition of spice into milk candy increase the calcium content considerably from 51.70 to 106.90 mg/100g. Calcium is essential for bone and teeth formulation, blood and extracellular fluid, necessary for normal functioning of cardiac muscles, and blood coagulation. The sodium content of spiced-milk candy is relatively lower ($p \leq 0.05$) with the values of 7.80–11.40 mg/100g, while milk candy without spice had 32.70 mg/100g. Sodium is essential for maintaining electrolyte balance but its excessive intake lead to hypertension [60]. The low quantity of sodium in spiced-milk candy indicate it as functional product with more potential health benefits. The minerals in milk candy fortified with spices have important interrelationships, regulate the fluid balance of the body and hence, influence the cardiac output.

3.6. Antioxidant activities of spiced-milk candy

Fig. 3 shows the antioxidant activity of milk candy with spice and without spice. Milk candy without spices had the lowest anti-oxidant activity of 14.6 %, 15.4 % and 18.5 % against Fe, OH and DPPH, respectively. Addition of *Aframomum melegueta* into milk candy improved its antioxidant potential with the highest scavenging activity of 58.30 % against OH. Milk candy fortified with *Xylopia aethiopica* and milk candy with *Ocimum gratissimum* have the same value (55.7 %) of scavenging activity against OH. Milk candy with

Table 5
Mineral composition (mg/100g) of spiced milk candy.

Samples	Potassium	Iron	Zinc	Phosphorus	Calcium	Sodium
CCT	73.30 ± 0.60^{j}	43.90 ± 3.50^{e}	48.80 ± 0.05^{i}	20.80 ± 0.02^{f}	51.70 ± 0.06^{i}	32.00 ± 0.30^{a}
CAP	318.10 ± 3.20^{c}	109.20 ± 0.55^{b}	133.60 ± 1.10^{a}	78.60 ± 1.00^{b}	79.80 ± 0.80^{e}	9.40 ± 0.07^{c}
CNP	292.30 ± 2.60^{d}	142.40 ± 2.90^{a}	81.70 ± 0.70^{cd}	104.60 ± 0.85^{a}	106.90 ± 4.90^{b}	10.75 ± 0.50^{b}
CCN	215.10 ± 1.30^{i}	83.10 ± 1.30^{cd}	77.00 ± 0.10^{d}	106.40 ± 1.76^{a}	97.10 ± 0.50^{c}	8.05 ± 0.05^{d}
CAB	287.60 ± 1.06^{de}	77.50 ± 0.10	101.80 ± 0.65^{b}	72.70 ± 0.80^{c}	80.80 ± 0.10^{e}	10.00 ± 0.23^{b}
CGG	275.00 ± 4.55^{e}	80.85 ± 0.20^{d}	98.20 ± 0.10^{b}	81.10 ± 0.70^{b}	117.10 ± 1.40^{a}	9.70 ± 0.06^{c}
CUU	241.90 ± 3.30^{f}	108.30 ± 1.90^{b}	105.60 ± 0.30^{b}	101.50 ± 1.10^{a}	85.30 ± 1.50^{d}	10.10 ± 0.30^{b}
CCC	347.90 ± 2.10^{b}	76.30 ± 0.80^{d}	72.20 ± 0.70^{e}	61.40 ± 0.96^{d}	101.00 ± 0.20^{c}	9.50 ± 0.40^{c}
CCI	432.50 ± 7.30^{a}	78.80 ± 1.10^{d}	60.90 ± 1.10^{f}	42.60 ± 1.04^{e}	78.90 ± 1.30^{e}	7.80 ± 1.10^{d}
CFE	279.90 ± 4.05^{e}	90.50 ± 0.70^{c}	84.20 ± 1.10^{c}	44.70 ± 1.20^{e}	107.70 ± 1.10^{b}	9.20 ± 0.00^{c}
CCU	301.10 ± 7.90^{d}	111.30 ± 5.70^{b}	75.10 ± 1.70^{d}	80.30 ± 3.00^{b}	87.70 ± 2.70^{d}	11.40 ± 0.00^{b}
CFN	239.80 ± 2.00^{f}	83.20 ± 3.60^{cd}	88.80 ± 1.10^{c}	64.10 ± 1.60^{d}	61.70 ± 2.20^{f}	9.50 ± 0.03^{c}

Values within the same column having the same alphabet are not significantly different ($p \geq 0.05$).
Key: CCT: milk candy without spices, milk candy with CAP: *Aframomum melegueta*, CNP: *Xylopia aethiopica*, CCN: *Monodora myristica*, CAB: *Ocimum gratissimum*, CGG: *Zingiber officinale* powder, CUU: *Piper guineense* seed, CCC: *Syzygium aromaticum*, CCI: *Cinnamomum burmannii*, CFE: *Trigonella foenum-graecum*, CCU: *Cuminum cyminum*, and CFN: *Foeniculum vulgare*.

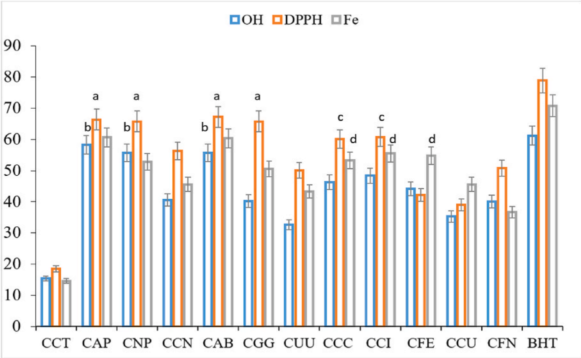


Fig. 3. Antioxidant activities of spiced milk candy at 100 μg/mL
Antioxidant activity of milk candy against OH, DPPH, and Fe with similar alphabets were not significantly different from each other at p ≤ 0.05. Error bars in the figure represent standard deviations (SD).
Key: CCT: milk candy without spices, milk candy with CAP: *Aframomum melegueta*, CNP: *Xylopia aethiopica*, CCN: *Monodora myristica*, CAB: *Ocimum gratissimum*, CGG: *Zingiber officinale* powder, CUU: *Piper guineense* seed, CCC: *Syzygium aromaticum*, CCI: *Cinnamomum burmannii*, CFE: *Trigonella foenum-graecum*, CCU: *Cuminum cyminum*, CFN: *Foeniculum vulgare*, and BHT: butylated hydroxytoluene.

Xylopia aethiopica or with *Zingiber officinale* have the highest ($p \leq 0.05$) and a similar value of scavenging activity of 65.80 % against DPPH. Milk candy with *Syzygium aromaticum* (60.1 %) and *Cinnamomum burmannii* (60.80 %) have similar ($p \leq 0.05$) scavenging activity against DPPH. Milk candies with *Aframomum melegueta* and *Ocimum gratissimum* displayed similar Fe chelation with values of 60.70 % and 60.40 %, respectively. Milk candies with *Syzygium aromaticum, Trigonella foenum-graecum*, and *Cinnamomum burmannii* also have a similar ($p \leq 0.05$) chelation activity of 53.30 %, 54.80 %, and 55.50 %, respectively against Fe. Matcha-based hard candy incorporated with *Zingiber officinale*, *Cinnamomum zeylanicum*, *Cinnamon cassia*, and *Ocimum sanctum* exhibited potential antioxidant activities [55]. The researcher attributed the antioxidant activity of phenolic compounds in spices. Antioxidants play a vital role as health protecting agents especially in foodstuffs as they respond to scavenging free radicals, delay and prevent food spoilage. Hence, antioxidant compounds in aromatic herbs and spices can be exploited in the food industry.

3.7. Prebiotic activity of the spiced milk candy

Fig. 4 shows the growth rate of *Lactobacillus fermentum* and *Lactobacillus acidophilus* on spiced-milk candy. The growth rate of *Lactobacillus fermentum* and *Lactobacillus acidophilus* was reduced as 2.2×10^5 CFU/mL and 1.4×10^5 CFU/mL in milk candy without spices. Milk candy containing *Cuminum cyminum* displayed prebiotic activity by supporting the growth of *Lactobacillus fermentum* and *Lactobacillus acidophilus* with the highest values of 8.30×10^5 cfu/mL and 6.90×10^5 cfu/mL, respectively. Cumin seeds displayed nutraceutical effects and can be used as traditional medicine to aid digestion, inhibit in the incidence of diarrhea, and to delaying the defecation time [61].

Milk candy containing spices displayed better prebiotic activity by supporting the growth of *Lactobacillus fermentum* and *Lactobacillus acidophilus*. The findings of Lu et al. [62] ascertained some spices namely; black pepper, cayenne pepper, cinnamon, ginger, Mediterranean oregano, and rosemary as dietary sources with prebiotic-like effect due to stimulating the growth of 17 strains of *Bifidobacterium* spp. and 16 strains of *Lactobacillus* species. Medicinal herbs and spices have potential health benefits through antioxidant, antimicrobial activities, and promoting the positive microbial modulation by stimulating beneficial gut bacteria [63]. Exploitation of medicinal herbs and spices using modern biotechnology and metabolic engineering to produce novel bioactive compounds with antioxidant, anti-cancer, anti-inflammatory, and antimicrobial mechanistic functions is needed to support the uses of conventional foods.

4. Conclusion

The selected herbs and spices used in this study contain useful and medicinal phytochemicals that are capable to exert potent antimicrobial and antioxidant activities against spoilage microorganisms and superoxide radicals, known to responsible for food deterioration. Incorporation of spices into milk candy produce healthy as value-added and good quality products to consumers. The utilization of spices with milk powder in preparation of candy improve the nutritional, and sensory properties of the final dairy product. The outcome of organoleptic property evaluation indicated that milk candies fortified with herbs and spices were well accepted, consistently received high scores in colour, taste, texture, mouth feel, and flavour, making them to standout and more appealing to consumers. The addition of herbs and spices into milk improve the antioxidant activities and supported the growth of probiotics. The production of functional milk candy with spices can increase the market's revenue due to the wide acceptance by consumers. The inclusion of herbs and spices into milk candy will serve some therapeutic values, boosts immunity, and can be advantageous to people of all ages, especially adults and immune-compromised patients. The study demonstrated the viability of using locally available herbs and spices to naturally fortify milk and its products.

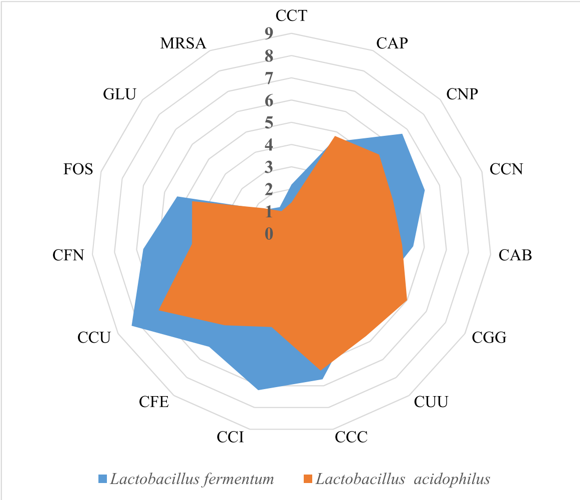


Fig. 4. Growth rate (x 10^5 CFU/mL) of probiotics in the presence of spiced milk candy.
Key: CCT: milk candy without spices, milk candy with CAP: *Aframomum melegueta*, CNP: *Xylopia aethiopica*, CCN: *Monodora myristica*, CAB: *Ocimum gratissimum*, CGG: *Zingiber officinale* powder, CUU: *Piper guineense* seed, CCC: *Syzygium aromaticum*, CCI: *Cinnamomum burmannii*, CFE: *Trigonella foenum-graecum*, CCU: *Cuminum cyminum*, and CFN: *Foeniculum vulgare*, MRSA**:** de Man, Rogosa and Sharpe**,** GLU: Man, Rogosa and Sharpe + glucose, FOS: Man, Rogosa and Sharpe + fructose oligosaccharides.

CRediT authorship contribution statement

Adeyanmola Oluwaseyi Faturoti: Methodology, Formal analysis, Data curation, Conceptualization. **Clement Olusola Ogidi:** Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization.

Ethics approval and consent to participate

The consent of participants were obtained. The sensory evaluation was carried out under the supervision of other researchers and ethics required were duly followed.

Consent for publication

All authors have read and approved the final version of the manuscript for publication**.**

Availability of data and materials

The authors confirm that the data supporting the findings of this study are available within the article.

Funding

Not applicable.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Not applicable.

References

[1] M.T. Baker, P. Lu, J.A. Parrella, H.R. Leggette, Consumer acceptance toward functional foods: a scoping review, Int. J. Environ. Res. Publ. Health 19 (3) (2022) 1217, https://doi.org/10.3390/ijerph19031217.
[2] E. Betoret, N. Betoret, D. Vidal, P. Fito, Functional foods development: trends and technologies, Trends Food Sci. Technol. 22 (9) (2011) 498–508.

[3] S.S. Fernandes, M.S. Coelho, M. de las Mercedes Salas-Mellado, Bioactive compounds. Bioactive Compounds as Ingredients of Functional Foods: Polyphenols, Carotenoids, Peptides from Animal and Plant Sources New, Woodhead Publishing, Cambridge, UK, 2019, pp. 129–142.
[4] S.M. El-Sayed, A.M. Youssef, Potential application of herbs and spices and their effects in functional dairy products, Heliyon 5 (6) (2019) e01989, https://doi.org/10.1016/j.heliyon.2019.e01989.
[5] A. Giannetti, G. Toschi Vespasiani, G. Ricci, A. Miniaci, E. di Palmo, A. Pession, Cow's milk protein allergy as a Model of food allergies, Nutrients 13 (5) (2021) 1525, https://doi.org/10.3390/nu13051525.
[6] Y.K. Luo, G.H. Bu, Cow's milk allergens and technologies to control allergenicity, in: Multidisciplinary Approaches to Allergies. Advanced Topics in Science and Technology in China, Springer, Berlin, Heidelberg, 2012, https://doi.org/10.1007/978-3-642-31609-8_25.
[7] G. Bu, Y. Luo, F. Chen, K. Liu, T. Zhu, Milk processing as a tool to reduce cow's milk allergenicity: a mini-review, Dairy Sci. Technol. 93 (3) (2013) 211–223, https://doi.org/10.1007/s13594-013-0113-x.
[8] S. Barak, D. Mudgil, Application of bioactives from herbs and spices for improving the functionality and shelf life of dairy products-A review, Biointerface Research in Applied Chemistry 13 (2) (2023) 141, https://doi.org/10.33263/BRIAC132.141.
[9] C. Martínez-Graciá, C.A. González-Bermúdez, A.M. Cabellero-Valcárcel, M. Santaella-Pascual, C. Frontela-Saseta, Use of herbs and spices for food preservation: advantages and limitations, Curr. Opin. Food Sci. 6 (2015) 38–43, https://doi.org/10.1016/j.cofs.2015.11.011.
[10] M. Samtiya, R.E. Aluko, T. Dhewa, J.M. Moreno-Rojas, Potential health benefits of plant food-derived bioactive components: an overview, Foods 10 (4) (2021) 839, https://doi.org/10.3390/foods10040839.
[11] A.B. Kunnumakkara, B.L. Sailo, K. Banik, C. Harsha, S. Prasad, S.C. Gupta, A.C. Bharti, B.B. Aggarwal, Chronic diseases, inflammation, and spices: how are they linked? J. Transl. Med. 16 (1) (2018) 14, https://doi.org/10.1186/s12967-018-1381-2.
[12] T.A. Jiang, Health benefits of culinary herbs and spices, J. AOAC Int. 102 (2) (2019) 395–411, https://doi.org/10.5740/jaoacint.18-0418.
[13] A. Roy, S. Das, I. Chatterjee, S. Roy, R. Chakraborty, Anti-inflammatory effects of different dietary antioxidants, in: H.M. Ekiert, K.G. Ramawat, J. Arora (Eds.), Plant Antioxidants and Health. Reference Series in Phytochemistry, Springer, Cham, 2022, https://doi.org/10.1007/978-3-030-78160-6_20.
[14] E.I. Opara, M. Chohan, Culinary herbs and spices: their bioactive properties, the contribution of polyphenols and the challenges in deducing their true health benefits, Int. J. Mol. Sci. 15 (10) (2014) 19183–19202, https://doi.org/10.3390/ijms151019183.
[15] V.K. Paswan, H. Rose, C.S. Singh, S. Yamini, A. Rathaur, Herbs and Spices Fortified Functional Dairy Products, IntechOpen, 2021, https://doi.org/10.5772/intechopen.98775.
[16] A. Sofowora, Medicinal plants and traditional medicine in african, Spectrum Book Ltd. Ibadan, Nigeria (1993) 13–43.
[17] G.E. Trease, M.C. Evans, Pharmacognosy, fourteenth ed., Elsevier, New Delhi, India, 2005, pp. 431–512, 53.
[18] C.O. Ogidi, V.O. Oyetayo, B.J. Akinyele, Microbial quality and antibiotic sensitivity profile of microorganisms isolated from street foods sold in Akure metropolis, Nigeria, Jordan J. Biol. Sci. 9 (4) (2016) 227–234.
[19] M. Cheesbrough, District Laboratory Practices in Tropical Countries, 2. second ed., Cambridge University Press, Cambridge, 2006 https://doi.org/10.1017/CBO9780511543470. Part.
[20] S.T. Cowan, K.J. Steel, Manual for the Identification of Medical Bacteria, third ed., Cambridge University Press, 1993, pp. 34–89.
[21] M.A. Gyamfi, M. Yonamine, Aaniya, Free radical scavenging action of medicinal herbs from Ghana; *Thonningia sanguine* on experimentally induced liver injuries, Gen. Pharmacol. 32 (1999) 661–667.
[22] B. Halliwell, J.M. Gutteridge, O.I. Aruoma, The deoxyribose method: a simple "test-tube" assay for determination of rate constants for reactions of hydroxyl radicals, Anal. Biochem. 165 (1) (1987) 215–219, https://doi.org/10.1016/0003-2697(87)90222-3.
[23] R.L. Puntel, C.W. Nogueira, J.B.T. Rocha, Kreb cycle intermediates modulate Thiobarbituric Acid Reactive Species (TBARS) production in rat brain *in vitro*, Neurochem. Res. 30 (2005) 225–235.
[24] Association of Official Analytical Chemists A.O.A.C, Official Methods of Analysis, *22*, Association of Official Analytical Chemists, Washington, D.C, 2012, pp. 35–60.
[25] N.M. Jose, C.R. Bunt, A.M. Hussain, Comparison of microbiological and probiotic characteristics of lactobacilli isolates from dairy food products and animal rumen contents, Microorganisms 3 (2015) 198–212.
[26] C.O. Ogidi, A.M. Ubaru, T. Ladi-Lawal, O.A. Thonda, O.M. Aladejana, O. Malomo, Bioactivity assessment of exopolysaccharides produced by *Pleurotus pulmonarius* in submerged culture with different agro-waste residues, Heliyon 6 (12) (2020) e05685, https://doi.org/10.1016/j.heliyon.2020.e05685.
[27] T. Soumya, T. Lakshmipriya, K.D. Klika, et al., Anticancer potential of rhizome extract and a labdane diterpenoid from *Curcuma mutabilis* plant endemic to Western Ghats of India, Sci. Rep. 11 (2021) 552, https://doi.org/10.1038/s41598-020-79414-8.
[28] A.O. Akintade, B.O.T. Ifesan, O.O. Awolu, T.M. Olaleye, Evaluation of physicochemical properties and sensory attributes of pumpkin seed (*Cucurbita maxima*) bouillon cube, J. Culin. Sci. Technol. (2022), https://doi.org/10.1080/15428052.2022.2123293.
[29] T. Anyamele, E.A. Ugbogu, Victor C. Nwankwo, C. Ibe, A review of the traditional uses, phytochemistry and toxicological profile of *Xylopia aethiopica* A. Rich, Pharmacological Research - Natural Products (2023), https://doi.org/10.1016/j.prenap.2023.100001.
[30] M.A. Rather, B.A. Dar, S.N. Sofi, B.A. Bhat, M.A. Qurishi, *Foeniculum vulgare*: a comprehensive review of its traditional use, phytochemistry, pharmacology, and safety, Arab. J. Chem. 9 (2) (2016) S1574–S1583, https://doi.org/10.1016/j.arabjc.2012.04.011.
[31] M.C. Ogwu, A. Dunkwu-Okafor, I.A. Omakor, S.C. Izah, Medicinal spice, *Aframomum melegueta*: an overview of the phytochemical constituents, nutritional characteristics, and ethnomedicinal values for sustainability, in: S.C. Izah, M.C. Ogwu, M. Akram (Eds.), Herbal Medicine Phytochemistry, Reference Series in Phytochemistry, Springer, Cham, 2024, https://doi.org/10.1007/978-3-031-21973-3_72-1.
[32] O.O. Olajuyigbe, O. Adedayo, R.M. Coopoosamy, Antibacterial activity of defatted and nondefatted methanolic extracts of *Aframomum melegueta* K. Schum. Against multidrug-resistant bacteria of clinical importance, Sci. World J. 2020 (2020) 4808432, https://doi.org/10.1155/2020/4808432, 2020.
[33] M. Kiralan, O. Ketenoglu, Food applications of clove (*Syzygium aromaticum*) extracts, in: Clove (Syzygium Aromaticum), Elsevier, Amsterdam, The Netherlands, 2022, pp. 607–617.
[34] H. Yan, M.D.G. Neves, B.M. Wise, I.A. Moraes, D.F. Barbin, H.W. Siesler, The application of handheld near-infrared spectroscopy and Raman spectroscopic imaging for the identification and quality control of food products, Molecules 28 (23) (2023) 7891, https://doi.org/10.3390/molecules28237891.
[35] C. Ibe, E.A. Irondi, E.A. Ugbogu, T. Anyamele, A review of the nutritional and antimicrobial properties of *Xylopia aethiopica* A.Rich, Food and Humanity (2023) 1099–1116, https://doi.org/10.1016/j.foohum.2023.09.007.
[36] J.Y. Talabi, S.A. Makanjuola, Proximate, phytochemical, and in vitro antimicrobial properties of dried leaves from Ocimum gratissimum, Prev. Nutr. Food Sci. 22 (3) (2017) 191–194.
[37] G.E. Batiha, L.M. Alkazmi, L.G. Wasef, A.M. Beshbishy, E.H. Nadwa, E.K. Rashwan, Syzygium aromaticum L. (Myrtaceae): traditional uses, bioactive chemical constituents, pharmacological and toxicological activities, Biomolecules 10 (2) (2020) 202, https://doi.org/10.3390/biom10020202.
[38] M. Saeed, M.S. Khan, M. Alagawany, et al., Clove (*Syzygium aromaticum*) and its phytochemicals in ruminant feed: an updated review, Rend. Fis. Acc. Lincei 32 (2021) 273–285, https://doi.org/10.1007/s12210-021-00985-3.
[39] Q.N. Okechukwu, F.U. Ugwuona, C.E. Ofoedu, S. Juchniewicz, C.O.R. Okpala, Chemical composition, antibacterial efficacy, and antioxidant capacity of essential oil and oleoresin from *Monodora myristica* and *Tetrapleura tetraptera* in Southeast Nigeria, Sci. Rep. 12 (1) (2022) 19861, https://doi.org/10.1038/s41598-022-23161-5.
[40] A.A. Mostafa, A.A. Al-Askar, K.S. Almaary, T.M. Dawoud, E.N. Sholkamy, M.M. Bakri, Antimicrobial activity of some plant extracts against bacterial strains causing food poisoning diseases, Saudi J. Biol. Sci. 25 (2) (2018) 361–366, https://doi.org/10.1016/j.sjbs.2017.02.004.
[41] Q. Liu, X. Meng, Y. Li, C.N. Zhao, G.Y. Tang, H.B. Li, Antibacterial and antifungal activities of spices, Int. J. Mol. Sci. 18 (6) (2017) 1283, https://doi.org/10.3390/ijms18061283.
[42] S. Akbari, N.H. Abdurahman, R.M. Yunus, O.R. Alara, O.O. Abayomi, Extraction, characterization and antioxidant activity of fenugreek (*Trigonella-Foenum Graecum*) seed oil, Materials Science for Energy Technologies 2 (2) (2019) 349–355.

[43] U.M. Srinivasa, A. Dalmia, A.W. Tumaney, et al., Exploring the lipidome, nutraceutical profile, anti-oxidant activity and physico-chemical properties of fixed oil derived from fenugreek (*Trigonella foenum-graecum* L.) seed fractions: a comparative analysis, Food Measure 18 (2024) 4388–4401, https://doi.org/10.1007/s11694-024-02501-1.
[44] O.S. Omoba, A.I. Olagunju, S.O. Salawu, A.A. Boligon, HPLC-DAD phenolic profiling and *in vitro* antioxidant activities of three prominent Nigerian spices, Preventive nutrition and food science 24 (2) (2019) 179–186, https://doi.org/10.3746/pnf.2019.24.2.179.
[45] O.C. Ugbogu, O. Emmanuel, G.O. Agi, C. Ibe, C.N. Ekweogu, V.C. Ude, M.E. Uche, R.O. Nnanna, E.A. Ugbogu, A review on the traditional uses, phytochemistry, and pharmacological activities of clove basil (*Ocimum gratissimum* L.), Heliyon 7 (11) (2021) e08404, https://doi.org/10.1016/j.heliyon.2021.e08404.
[46] V. Shukla, P. Development Kandra, physico-chemical and sensory evaluation of natural nutra candy, J. Food Sci. Technol. 52 (2015) 7535–7539, https://doi.org/10.1007/s13197-015-1810-7.
[47] R. Kailey, K. Dhawan, P. Rasane, J. Singh, S. Kaur, B.P. Singh, N. Kaur, D. Kaur, Utilization of *Foeniculum vulgare* in herbal candy preparation and analysing its effect on the physico-chemical and sensory properties, Curr. Sci. 116 (12) (2019) 2013–2019. https://www.jstor.org/stable/27138171.
[48] J.C. Acuff, J.S. Dickson, J.M. Farber, E.M. Grasso-Kelley, C. Hedberg, A. Lee, M.-J. Zhu, Practice and progress: updates on outbreaks, advances in research, and processing technologies for low-moisture food safety, J. Food Protect. 86 (1) (2023) 100018, https://doi.org/10.1016/j.jfp.2022.11.010.
[49] M.V. Zambrano, B. Dutta, D.G. Mercer, H.L. MacLean, M.F. Touchie, Assessment of moisture content measurement methods of dried food products in small-scale operations in developing countries: a review, Trends Food Sci. Technol. 88 (2019) 484–496, https://doi.org/10.1016/j.tifs.2019.04.006.
[50] R. Ergun, R. Lietha, R.W. Hartel, Moisture and shelf life in sugar confections, Crit. Rev. Food Sci. Nutr. 50 (2) (2010) 162–192, https://doi.org/10.1080/10408390802248833.
[51] H. Wazzan, Fortification of dairy products using plant-derived bioactive compounds, Nutr. Food Sci. 12 (2) (2024).
[52] S.K. Gill, M. Rossi, B. Bajka, et al., Dietary fibre in gastrointestinal health and disease, Nat. Rev. Gastroenterol. Hepatol. 18 (2021) 101–116, https://doi.org/10.1038/s41575-020-00375-4.
[53] E.C. Deehan, V. Mocanu, K.L. Madsen, Effects of dietary fibre on metabolic health and obesity, Nat. Rev. Gastroenterol. Hepatol. 21 (2024) 301–318, https://doi.org/10.1038/s41575-023-00891-z.
[54] G. Wu, Dietary protein intake and human health, Food Funct. 7 (3) (2016) 1251–1265, https://doi.org/10.1039/c5fo01530h.
[55] K. Dhawan, P. Rasane, J. Singh, S. Kaur, D. Kaur, H. Avinashe, et al., Effect of spice incorporation on sensory and physico-chemical properties of matcha-based hard candy, ACS Omega 8 (32) (2023) 29247–29252, 2023.
[56] V. Dixit, S.W.J. Kamal, P.B. Chole, D. Dayal, K.K. Chaubey, A.K. Pal, J. Xavier, B.T. Manjunath, R.K. Bachheti, Functional foods: exploring the health benefits of bioactive compounds from plant and animal sources, J. Food Qual. 2023 (2023) 5546753.
[57] E.S. Oh, K.S. Petersen, P.M. Kris-Etherton, C.J. Rogers, Spices in a high-saturated-fat, high-carbohydrate meal reduce postprandial proinflammatory cytokine secretion in men with overweight or obesity: a 3-period, crossover, randomized controlled trial, J. Nutr. 150 (6) (2020) 1600–1609, https://doi.org/10.1093/jn/nxaa063.
[58] C.M. Weaver, Potassium and health, Adv. Nutr. 4 (3) (2013) 368S–377S, https://doi.org/10.3945/an.112.003533.
[59] A. Nakamura, T. Kido, Y. Seki, M. Suka, Zinc deficiency affects insulin secretion and alters insulin-regulated metabolic signaling in rats, J. Trace Elem. Med. Biol. 83 (2024) 127375, https://doi.org/10.1016/j.jtemb.2023.127375.
[60] N. Graudal, The data show a u-shaped association of sodium intake with cardiovascular disease and mortality, Am. J. Hypertens. 28 (2014) 424–425, https://doi.org/10.1093/ajh/hpu236.
[61] K. Srinivasan, Cumin (Cuminum cyminum) and black cumin (Nigella sativa) seeds: traditional uses, chemical constituents, and nutraceutical effects, Food Quality and Safety 2 (2018) 1–16, https://doi.org/10.1093/fqsafe/fyx031.
[62] Q.Y. Lu, P.H. Summanen, R.P. Lee, J. Huang, S.M. Henning, D. Heber, S.M. Finegold, Z. Li, Prebiotic potential and chemical composition of seven culinary spice extracts, J. Food Sci. 82 (8) (2017) 1807–1813, https://doi.org/10.1111/1750-3841.13792.
[63] S.M. Dahl, V. Rolfe, G.E. Walton, G.R. Gibson, Gut microbial modulation by culinary herbs and spices, Food Chem. 409 (2023) 135286.