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PROXIMATE, MINERAL COMPOSITION, AND PHYSICOCHEMICAL PROPERTIES OF TWO FLAVOURED ICE CREAMS WITHIN BENIN CITY METROPOLIS, NIGERIA

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ABSTRACT

This research work covers the purchase of strawberry and vanilla-flavoured ice cream sourced locally from two different ice creamery outlets within the Benin Metropolis, Edo State, Nigeria. This involves the determination of the proximate composition (crude protein, crude fat, ash content, crude fibre, moisture, and carbohydrates obtained by difference) and the mineral composition (potassium, magnesium, calcium, molybdenum, iron, zinc, sodium, and copper) using the standard method. The physiochemical properties of both ice cream samples (temperature, pH, total solids, and sugar content) were carried out using the standard method. The (66.90 and 57.80%), (12.10 and 11.80%), (4.07 and 3.99%), (2.50 and 2.20%), (1.01 and 1.10%), and (13.41 and 23.11%) as in moisture contents, crude lipid, crude protein, crude fibre, ash content, and carbohydrate, respectively, were obtained for strawberry and vanilla flavour ice cream. Copper, zinc, iron, magnesium, calcium, sodium, and potassium were (0.23 and 0.24 mg/L), (1.27 and 1.28 mg/L), (2.20 and 2.22 mg/L), (0.49 and 0.50 mg/L), (2.90 and 2.90 mg/L), (3.66 and 3.67 mg/L), and (3.37 and 3.36 mg/L), respectively. The calorie contribution from carbohydrate and protein was lower, while it was higher in fat. The micronutrient ratio was within the expected range except for K/Na, Ca/Mg, and Ca/protein. The trace elements Zn, Cu, and Fe contributed the highest percentage of micronutrients needed to meet the daily requirement for proper functioning and development of a healthy body. Hence, it is recommended to be safe for consumption if taken cautiously and in moderation.

Keywords: Ice-cream, dietary contribution, micronutrient ratio, hidden hunger.

INTRODUCTION

Ice cream is a frozen snack or dessert made of lipid particles, air cells, ice crystals, and a serum with polysaccharides, proteins, lactose, vitamins, and mineral salts. There are different flavours, among which are vanilla, strawberry, and chocolate. It may be served in a bowl and eaten with a spoon or licked from edible wafer cones. Ice cream is a high-fat food with at least 10% milk fat but not more than 16% to be designated ice cream. It is expected to have <20% milk solids, not fat (MSNF) from milk (condensed, dry, whey, evaporated, and cream milk), along with flavour, stabilizer (>0.5%), and emulsifier.

Many industries manufacture ice cream at the global level, such as General Mills, Unilever, Nestle, Cold Stone Creamery, *etc.* (Grand View Research, 2022). Ice cream is one of the most popular end users of fast food across the globe among consumers; quality lifestyles, different flavours, and innovations are driving its demand. The global ice cream market was valued at USD 79.0 billion in 2021 and is expected to expand at a compound annual growth rate (CAGR) of 4.2% from 2022 to 2030 (Grand View Research, 2022). Ice cream production in Nigeria has recorded impressive growth. The Nigerian ice cream market recorded retail prices of USD 395 million in 2015, with a forecast of 1.75 billion USD by 2025 at an increasing CAGR of 15.8% per annum for the period 2020–2025 (Wmstrategy Blog, 2021).

Ice cream has carbohydrates, fats, and proteins, as well as calcium, phosphorus, and vitamins A, B-1, B-2, B-3, B-6, B-12, C, D, E, and K. While some researchers have keyed into the nutritional advantages and components of ice cream, recent studies and literature entail just minute accounts of the nutritional value of frozen foods, especially those locally produced in Nigeria (Legassa, 2020). As a result, determining the nutritional value of ice cream will assist in controlling the side effects associated with hidden hunger.

MATERIALS AND METHODS

All reagents: concentrated sulphuric acid, potassium hydroxide, methanol, chloroform, Kjeldahl's catalyst, concentrated hydrochloric acid, alkaline phenate, sodium hypochlorite, and sodium potassium tartrate were analytical grade. These instruments: muffle furnace (Carbolite Model), a drying oven (DHG-9023A Model), a refractometer (Abbe DR-M2/15501A Model), a pH meter (Jenway Model 3030), an atomic absorption spectrometer (Buck Scientific 210VGP Model), and a flame photometer (Sherwood Model 410) were used.

Source of Materials and Preparation

Cups of strawberry and vanilla-flavoured ice cream were purchased from two different ice creamery outlets at Ugbowo in Benin Metropolis in October 2022. The samples were defrosted in lukewarm water and transferred to reagent bottles, with each bottle identified specifically for different types of analysis. Then the samples were stored in a freezer prior to use for preservation, and they were used within three days.

Physiochemical Analysis

The physiochemical analysis was carried out to determine the sugar levels, pH, and temperature. The sugar level was analysed using a digital refractometer. The melted ice cream was dropped on the measuring hole of a portable refractometer, and it was measured in Brix according to Okamura *et al.* (2016). The mercury-in-glass thermometer was used to determine the temperature. The pH meter was initially calibrated with buffers 4 and 7 solutions before analysis of the sample began. This was performed in triplicate and in accordance with standard methods (Hanna instrument, 2024).

Proximate Analysis

The proximate constitution of the ice cream samples was investigated using the AOAC methods for moisture, ash, total solids, crude fibre, crude lipid, and crude protein (AOAC, 2005; Ovonramwen, 2021). The percentage of carbohydrates was calculated by taking the total sum of all other parameter percentages mentioned above and subtracting 100 (AOAC, 2005; Ovonramwen, 2021). They were all carried out in triplicate.

Estimation of Calorific Value

The calorific value was estimated from the values gotten from Crude fat extract (CFE), Crude protein (CP), and Total carbohydrate (TC) multiplied with the United Kingdom Department of Health constant (UKDH, 2013), as expressed below in Equation 1.

$$\text{Calorific Energy (CE)} = (\text{CFE} \times 9.00) + (\text{CP} \times 4.00) + (\text{TC} \times 3.75) \quad (1)$$

Mineral Analysis

The ash obtained from the proximate analysis was dissolved with HCl (10 mL, 2 M), cooled, and filtered. The filtrate was made up to the 100-mL mark with distilled water in a volumetric flask. The solution was then transferred to a cleaned and dried reagent bottle, which was labelled accurately, stored, and used for mineral determination. Mg, Cu, Fe, Zn, and Ca were analysed using an atomic absorption spectrometer (Buck Scientific, 210 VGP). Na and K in the same solution were analysed using a flame spectrophotometer (Buck Scientific 210VGP model-Buck Scientific Equipment Inc). These were performed in triplicate and according to the standard methods (AOAC, 2005).

The percent daily value (DV) of minerals, total carbohydrate and crude protein were calculated using the Equation 2 shown below:

$$\%\ DV = \frac{Amount\ of\ minerals, total\ carbohydrate\ and\ crude\ protein}{Recommended\ daily\ value} \quad 2$$

Statistical analysis

The means, standard deviation, and one-way ANOVA were carried out using Microsoft Excel 2016.

RESULTS AND DISCUSSION

The proximate composition of the ice cream samples is presented as both means and standard deviation (Table 1) and % calorific values (Table 2). The moisture content is a significant constituent of the proximate analysis that helps

quantify the amount of water in the sample. For dairy products, the moisture contents of strawberry (sample A) and vanilla (sample B) were 66.90 and 57.80%, respectively. The values of sample A fell within the range of 63.03–68.46% reported (De Meneses *et al.*, 2021). Meanwhile, the value of sample B was within the range; this is similar to the reported values 56.9, 60.5, and 57.9% in another author's study (Choi and Shin, 2014). The water contents are needed to boost the body's water for easy transportation, digestion, and absorption of food. The ice creams are high in water content. Hence, they will have a low shelf life. The crude lipid of the strawberry sample (12.10%) was a bit higher than that of the vanilla sample (11.80%). However, there were no significant differences between the two ice creams ($p > 0.05$). These two ice cream flavours fell within the range of reported regular ice cream (Sim *et al.,* 2020; Hossain *et al.,* 2021) but were higher than the value reported by another researcher (De Meneses *et al.*, 2021). The crude proteins from both samples (4.07 and 3.99%) compared favourably with other similar works of 3.99% (Batista *et al.,* 2019). The value was lower than what was reported by (Hossain *et al.,* 2021) but higher than 2.16-3.36% (Ogo *et al.,* 2021). In terms of the carbohydrate contents of the samples, B was higher than that of A. However, there were no significant differences between the two ice creams ($p > 0.05$). Although the value of vanilla flavour fell within the reported value 23.42% of Ogo *et al.* (2021), the value of strawberry was lower.

The crude fibre prevents a variety of health disorders, such as diverticulosis, bowel function disorder, constipation, and diarrhoea (Badgut.org, 2024). Also, it provides the bulkiness needed for easy gastric emptying and dilution processes, thereby preventing waste from staying too long in the large intestine. The crude fibre content in sample A ($2.50 \pm 0.173\%$) was higher than those in sample B ($2.20 \pm 1.155\%$) but were within the range 1.77- 2.95 % reported (Ogo *et al.,* 2021).

The sample fat calorie contributions were higher than the 20–35% recommended for a healthy diet (NHMRC, 2013). This might be linked to an increased risk of obesity, coronary heart disease and certain types of cancer (WHO, 2024). The protein calorific values of the two samples did not fall within the recommended health values of 10–35%, as needed to reduce the risk of chronic diseases (NHMRC, 2013). Meanwhile, it will supply its amino acids to some extent as protein contributes to the growth of children and the maintenance of tissues in adults. The strawberry and vanilla sample's carbohydrate calorie contribution is lower than the 45–65% recommended healthy function as needed to reduce the risk of chronic diseases (NHMRC, 2013). The calorie contribution of the ice creams from carbohydrates and protein was lower and the fat contribution was higher to reduce the risk of chronic heart diseases, overweight, stroke, high blood pressure, cancer, diabetes, and others, associated to calorie contribution. Hence, it should be consumed moderately.

Ash is a gauge of minerals present in food. The ash contents in the two samples 1.02 and 1.10% are within the value 1.02 - 1.09% reported earlier by Agustin *et al.,* (2021). The mineral contents are reported as means and standard deviation (Table 3), the percentage daily value (%DV) of the minerals (Table 4), and the mineral ratios (Table 5). Sodium is needed for the proper conduct of nerve impulses and to contract and relax muscles (Harvard School, 2024). The difference in sodium in the strawberry sample (3.66 mg/L) was not significant at $p>0.05$ when compared to that of the vanilla sample (3.67 mg/L), and both were compared to their %DV. These revealed that their small concentrations would have health impacts such as maintain proper balance of water and minerals among others. Potassium was found to be 3.37 mg/L for sample A and 3.36 mg/L for sample B. Their comparison showed no significant difference in their concentrations at $p > 0.05$, and when consumed in this proportion, it would perform its unique role in maintaining normal cell function. The ratio of Na to K should be lower than 1 in food to prevent or manage the risk of high blood pressure (Park *et al.,* 2016). The studied ice creams were not within the ideal ratio.

Table 1. Proximate Composition of Strawberry and Vanilla flavour Ice Cream.

Parameters	A	B
Moisture Content (%)	66.90 ± 0.87	57.80 ± 0.27
Ash Content (%)	1.02 ± 0.03	1.10 ± 0.10
Crude Fat (%)	12.10 ± 0.27	11.80 ± 0.12
Crude Fibre (%)	2.50 ± 0.17	2.20 ± 1.16
Crude Protein (%)	4.07 ± 0.01	3.99 ± 0.02
Carbohydrate (%)	13.41 ± 0.01	23.11 ± 0.02

Sample A and B (Strawberry and Vanilla flavour Ice Cream respectively)

Table 2. Calorific Value of Sample A and Sample B.

Nutrients	Strawberry Ice Cream		Vanilla Ice Cream	
	Calories	% Calorific	Calories	Calories
Carbohydrates	50.27	28.65	86.66	41.50
Protein	16.28	9.28	15.96	7.64
Fats/Lipids	108.90	62.07	106.20	50.86
Total	175.45	100.00	208.82	100.00

Table 3. Mineral Analysis of Ice Cream Samples.

Minerals	A (mg/ L)	B (mg/ L)
Copper (Cu)	0.23 ± 0	0.24 ± 0
Zinc (Zn)	1.27 ± 0.173	1.28 ± 0.015
Iron (Fe)	2.20 ± 0.058	2.22 ± 0.153
Magnesium (Mg)	0.49 ± 0.141	0.50 ± 0.137
Calcium (Ca)	2.90 ± 2.696	2.90 ± 2.697
Sodium (Na)	3.66 ± 1.106	3.67 ± 1.106
Potassium (K)	3.37 ± 1.626	3.36 ± 1.626

Sample A and B (Strawberry and Vanilla flavour Ice Cream respectively)

Table 4. Percent daily value of Ice Cream Sample (A and B).

Minerals	4-8 years		9-13 years		14-18 years		19-30 years		31-50 years		51+ years	
	A	B	A	B	A	B	A	B	A	B	A	B
TC	10.31	17.78	10.31	17.78	10.31	17.78	10.31	17.78	10.31	17.78	10.31	17.78
CP	21.42	21.00	11.97	11.74	7.83-	7.13-	7.27-	7.13-	7.27-	7.13-	7.27-	7.13-
K	0.09	0.09	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Na	0.19	0.19	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Ca	0.29	0.29	0.22	0.22	0.22	0.22	0.29	0.29	0.29	0.29	0.24	0.24
Mg	0.38	0.38	0.20	0.21	0.12-	0.12-	0.12-	0.13-	0.12-	0.12-	0.12-	0.12-
Fe	22.00	22.20	27.50	27.75	14.67-	14.80-	12.22-	12.33-	12.22-	12.33-	27.50	27.75
Zn	25.40	25.60	15.88	16.00	11.55-	11.64-	11.55-	27.75-	11.55-	27.75-	11.55-	11.64-
Cu	52.27	54.54	32.86	34.29	25.84	26.97	25.56	26.67	25.56	26.67	25.56	26.67

Sample A and B (Strawberry and Vanilla flavour Ice Cream respectively); TC: Total Carbohydrate; CP: Crude Protein

Table 5. The ice creams nutrient ratio.

No	**Micronutrient ratio**		Ratio	Ideal ratio
1	Sodium: Potassium	1.0860	1.0923	<1, about 0.5
2	Calcium: Magnesium	5.9184	5.8000	1.70 – 2.00
3	Zinc: Copper	5.5217	5.3333	8-12
4	Iron: Copper	9.5652	9.25	10-15
5	Iron: Zinc	1.7323	1.7344	2
6	Calcium: Protein	7.1253	7.2682	20

Sample A and B (Strawberry and Vanilla flavour Ice Cream respectively)

Calcium is required in the body for strong bones, teeth, muscles, and the proper functioning of the nervous system (Ahluwalia *et al.,* 2021; Iyer *et al.,* 2024; NIAMS, 2024). Although Ca facilitates many body physiological processes like skeletal mineralization, mediating vascular contraction, muscle and hormonal function (Yu and Sharma, 2024), etc, very low concentrations will result in an increase in body weight and fat levels, which are risk factors for cardiovascular disease (Alomaim *et al*., 2019). There was no significant difference in Ca between sample A (3.66 mg/L) and sample B (3.67 mg/L).

Magnesium is an important component necessary for energy production and nucleic acid synthesis (Alawi *et al.,* 2021). It is required for muscular contraction, neuromuscular conduction, blood pressure regulation, and insulin metabolism, among others (Żwierełło *et al.,* 2020; Alawi *et al.,* 2021). The magnesium concentration found in sample A was 0.49 mg/L, while that of sample B was 0.50 mg/L. This indicates that ice cream is not a good source of magnesium. These samples would contribute minimally to the dietary macrominerals like Na, K, Ca, and Mg. The Ca/Mg ratio was higher. This has been reported to be associated with the risk of cancer and other chronic health diseases (Costello *et al*., 2021; Barrado *et al.,* 2022). Therefore, it is not ideal for healthy blood pressure and metabolic processes. The Ca/protein ratio was lower than the adequate ratio of 20. There might be a tendency for bone mass problems as a result of the inability of calcium to form insoluble salts like calcium carbonate, calcium phosphate, and calcium citrate, leading to osteoporosis. The contribution from protein, Ca, and Mg suggests a moderate consumption.

The zinc (1.27 mg/L) of the strawberry ice cream was lower than that of the vanilla ice cream (1.28 mg/L). Zinc is an important structural element in bone formation, wound healing, behavioural response, brain development, the functioning of the immune system, and growth (Hojyo and Fukada, 2016). It takes part in many catalytic and regulatory processes in the body. The % daily value of Zn for ages 14–51+ was 11.55–15.88% for both samples, with the highest at 25.60% for ages 4–8.

For the growth and development of the body, iron is a mineral that is important. The study showed that strawberry ice cream contained 2.20 mg/L and vanilla ice cream contained 2.22 mg/L. The daily value of the two samples was 12.22-27.50% for the ages. The ice cream had an ideal ratio for Fe and Zn absorption. This showed that the ice cream would contribute appreciable amounts of iron and zinc to the body.

Copper in the two samples contributes 25.56–54.54%, with lower values for adults above 19 years and higher values for 4–8 years of daily value. Zinc and copper are two essential trace minerals required in many biochemical reactions such as the synthesis of nucleic acids and proteins, carbohydrate metabolism, and antioxidant defence mechanisms among others and for health maintenance (Costa *et al*., 2023; Ferreira *et al*., 2024). Copper helps to reduce atherosclerosis and inflammation, maintain cardiovascular function, and improve fat metabolism (Kerkadi *et al.,* 2021). The trace elements Zn, Cu, and Fe contributed the highest percentage of micronutrients needed to meet the daily requirement for proper functioning of a healthy body.

The physicochemical properties of the ice creams are presented as mean and standard deviation (Table 6). The pH of the strawberry and vanilla-flavoured ice creams was 6.44 and 6.42, respectively. These compared well with 6.33 and 6.40 reported earlier by Bald *et al.* (2014) and De Meneses *et al.* (2021), respectively) but lower than the plant ice cream based on soy and sesame milk reported (Ghaderi *et al.,* 2021). The sugar contents 34.3831 and 35.5398 were similar to the reported values 34.7 - 36.6% (Choi and Shin, 2014). The sugar content has a relationship with water content, as the Brix level decreases, there will be an increase in water content. The total solid contents have an impact on the melting process of the ice cream as they increase the resistance to flow of the serum phase as the ice melts, which leads to a slower meltdown. On the other hand, ice creams with low levels of total solid content (up to 30%) melted quickly (Silva and Silva, 2011).

Table 6. Physiochemical Properties of Ice Cream Samples.

Parameters	A	B
pH	6.44 ± 0.01	6.42 ± 0.02
Sugar Level (Brix)	34.3831 ± 0.0008	35.5398 ± 0.274
Total solid (%)	33.097 ± 0.01	42.20 ± 0.02
Temperature (°C)	26.50 ± 0.01	26.5 ± 0.01

Sample A and B (Strawberry and Vanilla flavour Ice Cream respectively

CONCLUSION

In conclusion, the studied strawberry and vanilla flavour ice cream had substantial amount of the components of proximate and mineral analysed, with the calorie contribution from carbohydrate and protein being lower and the fat contribution being higher. The micronutrient ratios were within the expected ranges except for Na/K, Ca/Mg, and Ca/protein. The trace elements Zn, Cu, and Fe contributed the highest percentage of micronutrients needed to meet the daily requirement for proper functioning and development of a healthy body. Hence, it is safe for consumption if taken cautiously and in moderation.

REFERENCES

Agustin C., Nurliyani, Jamhari. (2021). Ice Cream Characteristic with Cured Egg Yolk Powder as Whipping Cream Replacer. *Jurnal Ilmu dan Teknologi Hasil Ternak* (JITEK). 16 (1): 11-20. doi: 10.21776/ub.jitek.2021.016.01.2

Ahluwalia, M., Kumar, M., Ahluwalia, P., Rahimi, S., Vender, J. R., Raju, R. P. Hess, D. C., Baban, B., Vale, F. L., Dhandapani, K. M., Vaibhav, K. (2021). Rescuing mitochondria in traumatic brain injury and intracerebral hemorrhages - A potential therapeutic approach. Neurochemistry International, 150, 105192.

Alawi, A. M. A., Badi, A. A., Huraizi, A. A. and Falhammar, H. (2021). Advances in Food and Nutrition Research, 96, 193-218. Chapter Six - Magnesium: The recent research and developments. doi: 10.1016/bs.afnr.2021.01.001

Alomaim H., Griffin P., Swist E., Plouffe L.J., Vandeloo M., Kumar A., Bertinato J. (2019). Dietary Calcium Affects Body Composition and Lipid Metabolism in rats. *PLoS ONE* 14 (1): e0210760. doi: 10.1371/journal.pone. 0210760

AOAC (Association of Official Agricultural Chemists) (2005). *Official Methods of Analysis of the AOAC*. 18th ed. Gaithersburg, M. D., The Association.

Badgut.org. (2024). Dietary Fibre. https://badgut.org/information-centre/health-nutrition/dietary-fibre/.

Bald J.A., Vincenzi A., Gennari A., Lehn D.N., Souza C.F.V. (2014). Características Físico-Químicas De Soros De Queijo E Ricota Produzidos No Vale Do Taquari, Rio Grande Do Sul. *Revista Jovens Pesquisadores*, 4 (3): 90-99. doi: 10.17058/ rjp.v4i3.4602

Barrado E., Parodi J., Escobedo-Monge Ma., Marcos-Temprano M., Marugan-Miguelsanz J. M. (2022). Magnesium Status and Calcium/ Magnesium Ratios in Aseries of Cyctic Fibrosis Patients. *Nutrients*. 14 (9): 1793. doi: 10.3390/nu14091793.

Batsista, N. N., Ramos, C. L., Vilela, L. F., Dias, D. R. and Schwan, R. (2019). Non-dairy ice cream based on fermented yam (Dioscorea sp.). *Food Science & Nutrition* 7 (5), 1899-1907. doi:10.1007/s42770-019-00059-5

Choi M-J., Shin K-S. (2014). Studies on Physical and Sensory Properties of Premium Vanilla Ice Cream Distributed in Korean Market. *Korean J. Food Sci. An*. 34 (6): 757-762. doi: 10.5851/kosfa.2014.34.6.757

Costa, M. I., Sarmento-Ribeiro, A. B. and Gonçalves, A. C. (2023). Zinc: From Biological Functions to Therapeutic Potential. *Int J Mol Sci*. 24(5), 4822. doi: 10.3390/ijms24054822

Costello R.B., Rosanoff A., Dai Q., Saldanha L.G., Potischman N. A. (2021). Perspective: Characterization of Dietary Supplements Containing Calcium and Magnesium and Their Respective Ratio-Is a Rising Ratio a cause for concern. *Adv Nutr* 12 (2): 291-297. doi: 10.1093/advances/nmaa160

De Meneses, R.B., Moura, D.C.C., De Almeida, D.T., Bispo, E.Ds., Maciel, L.F., Da Rocha-Leão, M.H.M., Conte-Junior, C.A. (2021). Impact of Different Dairy Wheys on Quality Parameters of Ice Cream. *Revista Brasileira de Ciências Agrárias* 16 (1): e8028. doi: 10.5039/agraria.v16i1a8028

Ferreira, A. M. D. C., Hureau, C., Facchin, G. (2024). Bioinorganic Chemistry of Copper: From Biochemistry to Pharmacology. *Inorganics* 12(4), 97. doi: 10.3390/inorganics12040097

Ghaderi S., Tehrani M.M., Hesarinejad M.A. (2021). Qualitative Analysis of the Structural, Thermal and Rheological Properties of a Plant Ice Cream Based on Soy and Sesame Milks. *Food science and nutrition* 9 (3): 1289-1298. doi: 10.1002/fsn3.2037

Grand View Research. (2022). *Ice Cream Market Size, Share & Trends Analysis Report By Product (Bars & Pops, Cups & Tub), By Type (Dairy & Water-based, Vegan), By Flavour (Chocolate, Vanilla, Fruit), By Region, And Segment Forecasts*, 2022 - 2030. Report ID: GVR-2-68038-072-9. 80, https://www.grandviewresearch.com/industry-analysis/ice-cream-market.

Hanna Instruments (2024). *Which buffer solutions should I use to calibrate my pH meter with?* https://knowledge.hannainst.com/en/knowledge/ph-calibration-which-buffer-solutions-should-i-use-to-calibrate-my-ph-meter-with.

Harvard School. (2024). Salt and Sodium. https://nutritionsource.hsph.harvard.edu/salt-and-sodium/

Hojyo S., Fukada T. (2016). Roles of Zinc Signaling in the Immune System. *J. Immunol. Res*. 6762343. doi: 10.1155/2016/6762343

Hossain M.K., Petrov M., Hensel O., Diakité M. (2021). Microstructure and Physicochemical Properties of Light Ice Cream: Effects of Extruded Microparticulated Whey Proteins and Process Design. *Foods*, 10, 1433. doi: 10.3390/foods 10061433

Iyer, M., Kantarci, H., Cooper, M.H., Ambiel, N., Novak, S. W., Andrade, L. R., Lam, M., Jones, G., Münch, A. E., Yu, X., Khakh, B. S., Manor, U. and Zuchero, J. B. (2024). Oligodendrocyte calcium signalling promotes actin-dependent myelin sheath extension. *Nat Commun* 15, 265. doi: 10.1038/s41467-023-44238-3

Kerkadi A., Alkudsi D.S., Hamad S., Alkeldi H.M., Salih R., Agouni A. (2021). The Association between Zinc and Copper Circulating Levels and Cardiometabolic Risk Factors in Adults: A Study of Qatar Biobank Data. *Nutrients*. 13 (8): 2729. doi: 10.3390/nu13082729

Kumar, R. R., Rao, P. H. and Arumugam, M. (2015). Lipid Extraction Methods from Microalgae: A comprehensive review. *Front. Energy Res*. 2, 2014. doi: 10.3389/fenrg.2014.00061

Legassa, O. (2020). Ice Cream Nutrition and Its Health Impacts. *J Food Nutr Sci* 7(1): 19-27.

NHMRC (National Health and Medical Research Council). (2013). *Dietary Guidelines*. Canberra: National Health and Medical Research Council. 16.

NIAMS (National Institute of Arthritis and Musculoskeletal and Skin Diseases). (2024). Calcium and Vitamin D: Important for Bone Health. https://www.niams.nih.gov/health-topics/calcium-and-vitamin-d-important-bone-health.

Okamura, M., Hashida, Y., Hirose, T., Ohsugi, R. and Aoki, N. (2016). A simple method for squeezing juice from rice stems and its use in the high-throughput analysis of sugar content in rice stems. *Plant Production Science*, 19 (2), 309–314. doi: 10.1080/1343943X.2015.1128099

Ogo O., Emmanuella B., Esienanwan E., Daniel E. (2021). Nutritional and Sensory Evaluation of Novel Ice Cream Products Formulated from Kunu-Zaki Fortified with Fruit Pulp. *Food and Nutrition Sciences*, 12: 439-451. doi: 10.4236/fns.2021.125034

Ovonramwen O.B. (2021). Proximate and Mineral composition of Vegetable Salad without Dressing. *Mal. J. Appl. Sci*. 47 (3): 1243-1251.

Park J., Kwock C.K., Yang Y.J. (2016). The Effect of the Sodium to Potassium Ratio on Hypertension Prevalence: A Propensity Score Matching Approach. *Nutrients*. 8 (8): 482. doi: 10.3390/nu8080482

Silva Jr.E., Silva L.S. (2011). Effect of Different Sweetener Blends and Fat Types on Ice Cream Properties. *Ciênc. Technol. Aliment*. 31, 217-220.

Sim S.R., Kim Y.S., Lee J.H. (2020). Monitoring the Crude Fat and Cholesterol Content and Fatty Acid Composition of Commercial Ice Cream Products in Korea. *Korean J. Food Preserv*. 27 (5): 544-554. doi: 10.11002/kjfp.2020.27.5.544

UKDH, (United Kingdom Department of Health). (2013). Nutrient analysis of fruit and vegetables. Institute of Food Research, Norwich Research Park, Colney, Norwich, NR4 7UA, Independent Nutritionist, Surrey, UK. 14.

WHO (2024). *Data / GHO / Indicator Metadata Registry List. Fat intake*. https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3418

Wmstrategy Blog. Nigeria: Ice Cream Market to grow at CAGR of 15.80% until 2025. (2021). Available at: https://www.wmstrategy.com/news/nigeria-ice-cream-market-to-grow-at-cagr-of-15-80-until-2025.

Yu, E. and Sharma, S. (2021). Physiology, Calcium. Treasure Island (FL): StatPearls Publishing; 2024 Jan-.

Żwierełło, W., Styburski, D., Maruszewska, A., Piorun, K., Skórka-Majewicz, M., Czerwińska, M., Maciejewska, D., Baranowska-Bosiacka, I., Krajewski, A. and Gutowska, I. (2020). Bioelements in the treatment of burn injuries – The complex review of metabolism and supplementation (copper, selenium, zinc, iron, manganese, chromium and magnesium). Journal of Trace Elements in Medicine and Biology 62, 126616. doi: 10.1016/j.jtemb.2020.126616