J Food Sci Technol (July 2022) 59(7):2605–2616
https://doi.org/10.1007/s13197-021-05279-y

ORIGINAL ARTICLE

Effect of coconut milk, tender coconut and coconut sugar on the physico-chemical and sensory attributes in ice cream

P. P. Shameena Beegum[1] · Jwala P. Nair[1] · M. R. Manikantan[1] · R. Pandiselvam[1] · Sandip Shill[2] · S. Neenu[3] · K. B. Hebbar[1]

Revised: 2 September 2021 / Accepted: 19 September 2021 / Published online: 24 October 2021
© Association of Food Scientists & Technologists (India) 2021

Abstract The investigation was aimed to understand the effect of coconut milk, tender coconut pulp, tender coconut water and coconut sugar on the qualitative attributes of ice cream. Five ice cream formulations were laid out to substitute the major ingredients of ice cream such as, dairy milk and butter with coconut milk, skim milk powder with tender coconut pulp, refined sugar with coconut sugar and potable water with tender coconut water. Two of the formulations were exclusively non-dairy, third one was the standard dairy ice cream, fourth formulation was with the inclusion of coconut sugar in the standard ice cream and the fifth one was standard ice cream with tender coconut and coconut sugar. Proximate composition of the raw materials revealed that coconut milk, tender coconut pulp and coconut sugar can contribute to the solids-non-fat content in ice cream. Significant effect ($p< 0.01$) was observed on physico-chemical qualities of the mix and ice cream. Total solids, density and total soluble solids of the ice cream mixes were positively correlated. Density, one of the key physical parameters was ranged from 0.98 to 1.13 g/ cm^3. Though coconut milk is acidic, the percent titratable values were within the limit. Non- dairy ice cream formulations obtained lower overrun ($p < 0.001$). There was a negative correlation between percent fat of ice cream and overrun. Crude fat and protein contents of the ice creams were ranged from 10.52–11.62 % and 3.42–4.94 % respectively. Inclusion of coconut products resulted in increased total phenolics and minerals (ash). Non-dairy formulations were preferred over dairy counterpart with respect to flavour and taste during the sensory evaluation carried out with four different age groups. Thus, the study enlightens the potential scope of utilization coconut products in ice cream industry. It also gave a lead towards developing non-dairy/ vegan delicacy on coconut.

Keywords Ice cream, coconut · Coconut milk · Coconut sugar · Tender coconut pulp · Tender coconut water · Non-dairy

Introduction

The production and consumption of frozen dairy products such as ice cream, kulfi, softy are increasing day by day. An increased demand for non-dairy probiotic products also have come mainly from vegetarianism, milk cholesterol content, and lactose intolerance (Aboulfazli et al. 2014). According to the U.S. National Library of Medicine (2020), a reduction in the digestion of lactose has appeared in 65% of the world population. In East Asia, 70–100% of people suffer from lactose intolerance (Aydar et al. 2020). Of late, non-dairy or plant based milk sources such as soy, coconut and almond have become more popular. Plant-based milk substitutes are used as an essential ingredient in many vegan food products such as plant-based ice cream, yogurt, cheese, kefir, butter, etc. Among them, soy based products including soy milk, ice cream, yogurt have been

✉ P. P. Shameena Beegum
shameena.pht@gmail.com

✉ M. R. Manikantan
manicpcri@gmail.com

[1] Division of PB& PHT, ICAR- Central Plantation Crops Research Institute, Kasaragod 671124, Kerala, India

[2] Division of Social Sciences, ICAR- Central Plantation Crops Research Institute Research Centre, Mohit Nagar, Jalpaiguri 735101, West Bengal, India

[3] Division of Crop Production, ICAR- Central Plantation Crops Research Institute, Kasaragod 671124, Kerala, India

explored well. However, limited numbers of studies have been carried out on the use of coconut milk and its solids to replace cow milk and milk solids in the dairy products especially in ice cream.

The common constituents of ice cream are milk fat (added in the form of milk and cream or butter), milk solids-non-fat (skim milk powder), sucrose (refined sugar), water, stabilizers & emulsifiers, flavour and colour (Junior and Lannes 2011; Sukumar De 1991). Milk fat interacts with other ingredients and enriches the flavour apart from giving body, smooth texture, mouth feel and creaminess to ice cream. During freezing/whipping, about two-thirds of the fat will be solid (the other third still liquid), and this plays an extremely important role in fat structuring. Blends of nondairy fats often mimic this two-thirds solid at 4 °C. Coconut milk can be the best substitute for dairy milk in the Asian countries especially in India where coconut is abundant and is an integral part of the daily diet. Incorporation of coconut products in ice cream and other frozen dessert is being practiced in countries like Thailand, Malaysia and Indonesia. In India, tender coconut pulp is added to ice cream and sold as premium product by several brands. There is a huge scope for coconut milk as a dairy substitute. Both coconut milk and dairy milk are technically oil in water emulsion where, fat is naturally stabilized with proteins in it. Majority of the fatty acids present in both are of saturated in nature. Interestingly, coconut milk is easy to digest and it contains abundance of minerals and antioxidants. Majority of the proteins in coconut milk are with essential amino acids. Various researchers have also found conclusive evidence that consumption of coconut milk can increase the HDL (high-density lipoprotein) levels, which help in reducing the harmful LDL (low-density lipoprotein) (Vanga and Raghavan 2018). However, while replacing dairy milk fat with coconut milk, it needs to simulate the desirable attributes of dairy milk especially fat globules, as they contribute to the desirable creamy appearance, texture, and mouth feel which itself is a great challenge. Similarly, the melting rate of coconut fat in ice cream would be higher as compared to dairy milk which also is another challenge. Sanful (2009) reported that coconut milk can provide creamy taste, smooth, and aromatic flavour to delicacies. Coconut fat does not contain trans-fatty acids but contains mono glycerides, which is readily absorbed by the body and converted into energy shortly after it is consumed.

Second ingredient of ice cream, the milk solids- non-fat (MSNF) gives perfect body, higher over run with good texture. Usually concentrated or dried milk sources are used. Skim milk powder is the widely accepted source of MSNF (Arbuckle 1986; Sukumar De 1991). Proteins are the main source of solids-non-fat. Proteins of milk are casein and whey protein. These milk proteins stick to the surface of fat droplets, creating a thin membrane. It helps to give body and a smooth texture to the ice cream, through emulsification of the fat, foam formation and stability of the air bubbles, and viscosity enhancement in the unfrozen phase. Besides, lactose present in milk and powder add total solids to the formulation, adds to the sweetness produced largely by the added sugars, and contributes also to the freezing point depression of the other sugar (Syed et al. 2018; Goff and Hartel 2016). Tender coconut pulp can be used as a partial or complete substitute for milk powder as it contains adequate protein in comparison with coconut milk. It is sweet and contains less sugar, more protein than many popular fruit, and is relatively higher in minerals such as iron, phosphorus and zinc (Silva and Bamunuarachchi 2009). It is a good source of carbohydrate, fiber and other nutrients (Chempakam and Arivalagan 2018). In addition, it has amino acids and other vitamins. 90% of the proteins in coconut are albumins and globulins (Naresh Kumar et al. 2018). Since these are different from dairy milk proteins their effect in ice cream need to be studied. Besides, the sweet water of tender coconut can function as substitute for potable water, to standardize the content of fat and MSNF in the ice cream mix. Tender coconut water, technically the liquid endosperm has a pleasant taste with good amount of nutrients. It has a total solids content of 6.5% with 0.01% protein and good amount of minerals especially potassium, sodium, calcium and iron (Chempakam and Arivalagan 2018).

The third ingredient, sucrose in the form of refined sugar, is the cheapest source of solids and the most widely used sweeteners in ice cream improves texture, palatability, viscosity and enhances sweet taste and flavor (Syed et al. 2018). However it provides high calories and higher glycemic index leading to limitation for consumers concerning with health or suffering from diabetes and obesity (Fuangpaiboon and Kijroongrojana, 2015). Substitution of refined sugar with coconut sugar which is made from coconut inflorescence sap may be a healthy alternative in ice cream as it has low glycemic index, supplies calories and nutrients. It has two, four and ten times the amount of iron, magnesium and zinc respectively. Besides, it contains all essential amino acids required for protein synthesis, and is rich in vitamins like B1, B2, B3 and B6 (Hebbar et al. 2015). It is gluten free, light brown in colour and has caramel, malty, sweet, and roasty smell (Wrage et al. 2019).

Stabilizers and emulsifies generally used in vey less quantity (maximum 0.5% as per FSSAI), are highly effective in giving body and smoothening the texture. Primary purposes for using stabilizers are to increase mix viscosity, to stabilize the mix, to aid in suspension of flavoring particles, to produce a stable foam with easy, to reduce ice and lactose crystal growth during storage, to slow down moisture migration from the product, to prevent shrinkage of the product volume during storage, to provide uniformity to the product and resistance to melting and produce smoothness in texture during consumption (Goff and Hartel 2013). Emulsifier particularly improves the whipping quality of the ice cream mix and reduces the time of whipping (Arbuckle 1986; Surapat and Rugthavon 2003). Codex has recommended a few stabilizers and emulsifiers suitable for coconut milk and milk products which can be explored for the effectiveness in ice cream. Keeping all these challenges in view, the present investigation was carried out to understand the effect of each ingredient on physico-chemical and sensory attributes in ice cream, there by to analyse the feasibility for developing vegetarian alternative to ice cream.

Material and methods

Raw Materials

Freshly harvested mature coconuts (12 months old) and tender nuts were (Chowghat Orange Dwarf) were procured from the experimental farm of ICAR-Central Plantation Crops Research Institute, Kasaragod for carrying out the research. Coconut milk was extracted using hydraulic milk expeller. First extraction of milk was taken without adding water. Second and third extractions were taken after adding 250 ml warm water (40 °C) per kilogram of residues respectively. Three extractions were pooled for carrying out the study. Freshly collected coconut inflorescence sap or Kalparasa® (trade mark of CPCRI for fresh and alcohol free sap) with an ideal pH and total soluble solid content of 7 and 14 °C Brix respectively was collected for preparing coconut sugar. It was concentrated at 115 °C by indirect heating in an open pan cooker designed at the Institute. During heating, the water content gets evaporated and the liquid changed into crystal form and was immediately cooled. While cooling, it was stirred continuously to break the lumps. Sugar obtained were sieved to get uniform particle size and to produce quality product which was then dried to a moisture content of less than 2%. Tender coconut (7–8 months old) was punched to collect the water and cut to scoop the pulp using tender coconut punch and cutter. All the raw materials were used immediately after extraction. Whole dairy milk was standardized before making the mix. Ingredients such as whole dairy milk, refined sugar, skimmed milk powder (Amulya, AMUL) and Butter (AMUL) were purchased from local market. Preliminary standardization was carried out to select the best suitable stabilizer and emulsifier combinations by screening the listed additives by Codex standards for aqueous coconut products (CODEX STAN 240–2003). Food grade stabilizers such as carboxymethyl Cellulose (CMC), guar gum, xanthan gum and emulsifier, glycerol monostearate (GMS) were selected and purchased from M/s. Viveka Essence Mart, Manglore, Karnataka. All the reagents used for chemical analysis were of analytical grade and purchased from M/s. Merk, New Delhi, India.

Preparation of ice cream formulations

The composition of different ice cream formulations is given in Table 1, which were made with the objective of getting a minimum total solid of 30%, fat content of 10–12%, acidity of 0.3% (max), sucrose level of 15% and 0.5% (max) stabilizers and emulsifier. Five formulations mainly consisted of; (1) coconut milk, tender coconut pulp, tender coconut water and refined sugar (2) coconut milk, tender coconut pulp, tender coconut water and coconut sugar, (3) control which was a commercial formulation of an established ice cream firm consisted of whole milk (standardized to 5–6% fat), butter, skimmed milk powder and refined sugar (4) refined sugar in the control was replaced with coconut sugar (5) tender coconut pulp and tender coconut water were added in addition to formulation 4. With these formulations, the effect of coconut milk, tender coconut pulp, tender coconut water and coconut sugar as a replacer to whole milk, skimmed milk powder, water and refined sugar respectively could be studied. The percentage composition in each formulation except control was standardized based on the result of preliminary experiments. The mix formulations were calculated by algebraic method. Standardization was also made for the level of ingredients and for stabilizers & emulsifiers. The standardized composition include 0.1% CMC, 0.07% xanthan gum, 0.03% guar gum and 0.3% GMS, All the ingredients were thoroughly mixed and pasteurized at 75 °C for 15 min followed by homogenization at 2000/500 psi, ageing at 5 °C for an hour and then the mix was added to a continuous freezer (provided with a compressor, aeration valve and a pressure gauge). The output was packaged in high density polyethylene (HDPE) containers followed by hardening at −28 °C. All the experiments were carried out with four replications with an input of 10 L per batch. The ingredients and proportion of the ice cream formulations are shown in Table 1. Appearance of the products is depicted in Fig. S1.

Physico-chemical quality evaluation of coconut milk, tender coconut pulp, tender coconut water and coconut sugar

pH was measured using a digital pH meter (Pctester 35,Eutech Instruments, Singapore). Total soluble solids were measured using a pocket refractometer (ATAGO,

Table 1 Dairy and coconut milk based ice cream formulations

Composition	Ice cream formulations (%) / Treatments				
	T1	T2	T3	T4	T5
Coconut milk (%)	23	23	–		
Dairy milk (%)	–	–	60	60	54
Sucrose (refined sugar) (%)	15		15		
Coconut sugar (%)		15		15	13
Tender coconut water (%)	50	50			10
Tender coconut pulp (%)	11.5	11.5			10
Skim milk powder (%)	–	–	6.2	6.2	5.5
Butter (%)			8	8	7
Water (%)			10.3	10.3	–
Stabilizers & emulsifier (%)	0.5	0.5	0.5	0.5	0.5

*3: Standard ice cream formulation

PAL-BX/RI Canada). Proximate composition was estimated using (AOAC 1995) standard methods. Fat content of coconut milk was estimated using Rose Gotlieb method (Lakshanasomya et al. 2011) with some modification using solvents such as ammonia, ethyl alcohol, diethyl ether and petroleum ether and with four extractions. Fat content of tender coconut pulp was measured using soxhlet method. Protein content (dry weight basis) in all the ingredients was measured using kjeldahl method.

Quality evaluation of the mix and ice cream

Density of the mix was determined using mass by volume method. Moisture, total solids, total soluble solids and pH of mix were estimated as per the method described in the previous heading. Titratable acidity was estimated by titration against standard NaOH solution in the presence of phenolphthalein indicator. Percent over run of the ice cream was calculated as per the following equation, (Marshall and Abruckle 1996).

$$Overrun(\%) = ((Weight\ of\ mix\ per\ unit\ volume - weight\ of\ delicacy\ per\ unit\ volume) / (Weight\ of\ delicacy\ per\ unit\ volume \times 100))$$

Crude fat content of ice cream was estimated by Rose Gotlieb method as mentioned above. Crude protein was estimated by kjeldahl method (fresh weight basis). Total sugar was estimated using phenol sulphuric acid method (Thimmaiah 1999). Total phenol estimation was carried out with Folin–ciocalteau reagent (Bray and Thorpe 1954).

Sensory evaluation

The sensory evaluation of ice cream samples was carried out using semi-trained judges of different age groups such as age group between 6–10 years, 11–15 years, 25–30 years, and 40–60 years. The total number of panelist was 40. Samples were coded with three digit random numbers and briefed before sensory evaluation. The elected sensory attributes were appearance & colour, textural properties such as meltdown, fat feel and iciness, flavour & taste. The ice cream cups were served immediately after withdrawing the cups from hardener chest after 24 h of storage and promptly offered to the panelists. Water was provided as taste neutralizer.

Statistical analysis

The result of physicochemical evaluation was analyzed using analysis of variance for the replicates with Duncan's multiple range test (DMRT). Analysis for sensory evaluation was done using Scheirer–Ray–Hare Test which is a two factor version of the Kruskal–Wallis test. Data was analyzed using the 'rcompanion package' (Salvatore 2018) followed by the non parametric post hoc test, namely Dunn test using the FSA package in R (Ogle 2018).

Results and discussion

Physico-chemical quality evaluation of coconut milk, tender coconut pulp, tender coconut water and coconut sugar

Table 2 shows the results of physico-chemical quality evaluation of the major ingredients. The high fat content of coconut milk (27.69 ± 5.34% wb) clearly indicated that before going for ice cream making, coconut milk needs to be either diluted or some proportion of cream has to be removed. Hence, for preparing non-dairy ice cream, we

Table 2 Physico-chemical quality evaluation of raw materials

Parameter	Coconut milk	Tender coconut pulp	Tender coconut water	Coconut sugar
pH	6.10 ± 0.1	6.64 ± 0.09	5.07 ± 0.1	–
Moisture (%)	57.32 ± 0.3	90.25 ± 0.38	92.62 ± 0.18	1.62 ± 0.29
Total solids (%)	42.67 ± 0.3	9.75 ± 0.38	7.38 ± 0.18	98.38 ± 0.29
Total soluble solids	12.1 ± 0.5	5.68 ± 1.12	5.41 ± 0.22	–
Crude fat (%)	27.69 ± 5.34 (wb)	13.04 ± 0.28 (db)	0.03 ± 0.02 (db)	Negligible
Crude protein (%) (db)	6.79 ± 0.05	7.95 ± 0.7	1.56 ± 0.05	2.84 ± 0.12
Ash (%)	2.84 ± 0.05	8.57 ± 0.09	8.33 ± 0.04	1.85 ± 0.19

*Values are mean ± standard deviation. wb: wet basis, db: dry basis

have diluted coconut milk with tender nut water to make the ice cream with at least 11% fat. Freshness of coconut milk is most critical in the preparation of ice cream as sweet curdling used to occur in coconut milk if it is kept for more than 5 h at ambient temperature. Coconut milk after extraction can be frozen or pasteurized, which can be used for ice cream production if there is a time delay in the mix preparation. It is ideal to establish a coconut milk extraction set up along with the ice cream making unit. Identical to dairy milk, coconut milk is comprises of water, milk fat, and milk solids-not-fat (MSNF). MSNF in dairy milk are the solids of skim milk include lactose, proteins, minerals and other minor components. (Mehta, 2015). Coconut milk (thrice extracted) had 57.32% moisture and 42.67% total solids, 27.69% fat, 6.79% (db) protein and 2.84% ash or minerals. Conversely, dairy milk consists of around 87% water, 4–5% lactose, 3- 4% fat, 3% protein, 0.8% minerals, and 0.1% vitamins (Pereira, 2014). The crude protein content in coconut milk was 6.79% (db). Central Food Technological Research Institute (CFTRI) has reported the proximate composition of coconut milk (db) at 4.1% moisture as 5.85% protein, 38–40% fat 6.25 minerals and 9–11% carbohydrate (Rethinam and Bosco 2006). Tansakul and Chaisawang (2006) also reported that coconut milk contains 54% moisture, 30–35% fat, and 11% solid non-fat (SNF), which includes 3–4% protein (wb) and mineral matter. Size of fat globule in dairy milk is around 4–5 µm (McClements et al. 2019), whereas, that of coconut milk 10–11 µm (Tangsuphoom and Coupland 2019). About 30% of the protein in coconut milk is dissolved in the aqueous phase and undissolved proteins associated with oil globules act as emulsifier. Coconut milk is reported to have minerals such as phosphorus, calcium and potassium as in dairy milk though in smaller amount than milk. (Seow and Gwee 1997). In place of lactose in dairy milk, coconut milk has sucrose and some starch as major carbohydrates. These contribute to the SNF content in coconut milk.

Tender coconut pulp was included with the objective of imparting the similar function of skimmed milk powder (SMP) in ice cream such as imparting the body, texture and over run. It has a crude protein and fat content of 7.95% (db) and 13.04% respectively. Tender nut pulp composed of 89% water, 12.73% protein, 24.09% fat, 5.27% ash on dry weight basis (Prapasuwannakul et al. 2014). However, it does not have casein (phosphoprotein), which is 80% of proteins in skim milk powder. Around 80% of the proteins in coconut pulp is albumins and globulins (Seow and Gwee, 1997). The exact effect of solids-non-fat content in tender nut pulp on ice cream needs is explored in this study. Prapasuwannakul et al. (2014) suggested that tender coconut pulp can be used as alternative ingredient to replace fat, milk stabilizer and emulsifier even in high carbohydrate ice cream formulation. When skim milk powder is added in ice cream, besides providing protein and mineral content, it contributes much to the development of structure in ice cream, including emulsification, whipping, viscosity/ thickening, texture, water holding, rheology, palatability and enhance flavour (Udabage et al. 2005; Goff and Hartel 2013). Tender coconut has not been explored for such kind of functional properties as there are limited studies on these aspects. Tender coconut water can be used to standardize the content of fat and MSNF in the ice cream as it can add source of solid non-fat (7.38%).

Coconut sap contains about 15% sugars and considerable amount of nutrients, vitamins and minerals. Coconut sugar is produced by concentrating the unfermented sap at 100–115 °C (1 kg sugar from 7 L sap) (Hebbar et al. 2015) Philippine Coconut Authority (2004) reported that coconut sugar has a low glycemic index (35 ± 4) and thus it is good for diabetics and suitable for weight maintenance. Besides, the protein present in coconut sugar (2.84%) can influence the ice cream properties. The proximate composition of all the above ingredients indicated its potential for substitution in ice cream preparation.

Quality evaluation of the mix and ice cream

Ice cream mix is the liquid mix containing all the ingredients of ice cream except the air (before freezing). Here, sugar would be in true solution, fat is in emulsion state while protein is in dispersion. As the coconut fat globule size is much higher in comparison to dairy milk fat, the mix was homogenized at 2000/500 psi, so as to make the fat globules smaller and uniform. Mix quality has crucial role in the quality of ice cream. The result of quality evaluation of the ice cream mix is shown in Table 3. The statistical analysis revealed that the model was significant ($p < 0.05$).

Moisture (%) and Total solids (%)

Total solids (TS) include protein, fat and other solids matter and the rest is moisture content. Total solids and moisture content of the mix ranged from 32.72% to 41.50% and 58.50% to 67.28% respectively ($p < 0.05\%$). Average moisture content in normal ice cream is approximately 61.7% (Arbuckle 1986). Total solids are one of the major parameters that directly affect the quality of ice cream. If these are in excess, then curded texture could result, while low contents resulted in ice crystal formulation and coarse texture (Amal et al. 2015). Even, slight variations in solid content of just a few percentages will greatly influence ice crystal growth. There is even high chance of ice crystal growth in dairy free ice cream formulations especially with coconut milk. Slight ice crystal growth was observed in T1 and T2 during storage which might be due to the differences in the type of proteins present in coconut. Coconut protein has very low water hydration capacity as compared to that of skim milk powder (Patil and Benjakul 2018). The solubility of coconut proteins is generally low between pH 4 and 5, and is increased when pHs are above or below such pH which can be correlated with the result obtained for pH. Onsaard et al. (2006) stated that proteins isolated from coconut skim milk effectively stabilized emulsions that are fairly viscous. The total solids in the coconut based formulations (T1 and T2) were comparatively lower than dairy based formulations. Formulation containing dairy milk, tender coconut pulp, tender coconut water and coconut sugar (T5) had the highest total solids. The absence of skimmed milk powder in T1 and T2 reduced the total solids. Incorporation of amla pulp led to decrease in total solids of ice cream whereas inclusion of amla preserve, candy and powder increased the solid content of ice cream mix (Goraya and Bajwa 2015) which revealed that addition of concentrated forms of coconut pulp such as coconut milk powder or protein powder would be more beneficial for ice cream making. However, Ahsan et al. (2015) reported total solids between 32.17–32.67% in soy milk based non-dairy ice-cream. Protein is one of the major components in total solids which contribute to emulsification, aeration, and solution behavior. Ice cream should contain a minimum of 2.5% protein. Proteins adsorb into fat globules at the time of homogenization which result in better emulsification property. Whipping properties of proteins in ice cream contribute to the formation of the initial air bubbles in the mix. The water holding capacity of proteins leads to enhanced viscosity in the mix, which imparts a beneficial body to the ice cream, increases the meltdown time of ice cream, and contributes to reduced iciness (Goff and Hartel, 2013). These properties are found to be limited with tender coconut pulp which could be increased with the addition of other non-dairy high protein ingredients such as soy protein, pea protein, brown rice protein etc. along with dairy free ice cream with tender coconut pulp and coconut milk. Maximum percent solids in T5 were owing to the increased protein content due to addition of skimmed milk powder, tender coconut pulp and coconut sugar. *pH.*

pH of the mix varied from 5.90 to 6.47 (Table 3). Significant effect of coconut products was visible from the data ($p < 0.01$). Dairy based formulation (T3) had the maximum pH (6.47) and after replacing refined sugar with

Table 3 Quality evaluation of ice cream mixes

Ice cream formulations	Crude fat (%)*	Crude protein (%)**	Total sugar (%)ns	Total phenolics (mg/100 g)**	Ash (%)**
T1	11.62 ± 0.06^{a}	3.42 ± 0.11^{c}	11.34 ± 0.91	32.33 ± 2.52^{bc}	0.46 ± 0.06^{c}
T2	11.61 ± 0.62^{a}	3.63 ± 0.06^{c}	10.78 ± 0.15	38.00 ± 2.65^{a}	0.59 ± 0.05^{c}
T3	10.53 ± 0.84^{b}	4.63 ± 0.12^{b}	10.63 ± 0.46	19.70 ± 0.85^{c}	0.67 ± 0.04^{bc}
T4	10.55 ± 0.05^{b}	4.94 ± 0.22^{a}	11.32 ± 0.59	28.27 ± 1.31^{ab}	1.13 ± 0.05^{ab}
T5	11.30 ± 0.18^{ab}	4.76 ± 0.09^{ab}	11.25 ± 0.78	31.90 ± 0.49^{ab}	1.45 ± 0.05^{a}

T1: Coconut milk with tender coconut (pulp and water) and refined sugar; T2: Coconut milk with tender coconut (pulp and water) and coconut sugar; T3: Dairy ice cream (control); T4: Dairy formulation with coconut sugar; T5: Dairy formulation with coconut sugar and tender coconut (pulp and water)

*ns non significant, *significant at 5%, **significant at 1%

[a, b, c]Different alphabets indicate that the values are statistically significant different from one another

coconut sugar (T4) and tender coconut pulp & water (T5) to it, pH reduced to 6.30 and 6.35 respectively. This reduction of pH value attributable to the increased percentage of acidity in the ice cream formulation containing coconut products. Moreover, the pH of dairy milk is higher than pH of coconut milk and tender coconut. pH of T1 and T2 (coconut based formulations) were 5.95 and 5.90 respectively. Arbuckle (1986) reported that the normal pH value of ice cream is about 6.3. Marshall et al. (2003) further stated that pH of ice creams varies with the composition of the product. Marshall and Arbukle (1996) reported a decrease in pH with increased total solids. Nonetheless, the result obtained in this study showed positive correlation of total solids and pH. This might be due to the ingredients used. pH of coconut milk ranges from 5.8 to 6.1 and that of dairy milk is 6.5–6.7. Certainly ice cream made with dairy milk would be having higher pH. pH was reduced further when dairy milk was added with tender coconut pulp (6.64 pH) and tender coconut water (5.07 pH).

Density (g/cm^3)

Density of ice cream mix varied from 0.98 g/cm^3 to 1.13 g/cm^3. It generally is in the range of 1.0544–1.1232 g/ cm^3 (Sukumar De 1991). Density of ice cream mix varied with composition. Formulation 5 (T5) had the maximum density of 1.13 ($p < 0.01$) which was due to the incorporation of tender coconut pulp along with skimmed milk powder to the mix. There was a positive correlation of total solids and density of mix. Bajad et al. (2016) reported that increased levels of solids-non-fat, sugars, and stabilizers increase the density, whereas increased fat decreases mix density. The result on density was in agreement with the above report.

Total soluble solids (°Brix)

TSS content in the formulations ranged from 22.55°Brix to 29.40 °Brix. Lowest and highest TSS was obtained for T2 (non-dairy) and T5 respectively. The result was in agreement with that of total solids. However, the effect was non significant ($p > 0.05$). These total soluble solids are generally from sugars, milk-solids-non-fat (SNF) stabilizers and emulsifiers.

Overrun (%)

According to Goff (1997), the air incorporation in ice cream must be between 10 and 50%. Thus, results of overrun values obtained in the ice cream formulations were in accordance with earlier report. It is related to the amount of air incorporated into the ice cream during the production which has affects the texture and physical properties of ice cream. Many factors such as proteins, fat, emulsifier and stabilizer are crucial in air incorporation and stabilization of air cells (Marshall et al. 2003). Generally, non-dairy based ice creams or frozen desserts have lesser overrun. The effect of non-dairy ingredients such as coconut milk, tender coconut and coconut sugar on overrun of ice cream was highly significant ($p < 0.001$). Overrun ratios varied from 40 to 86% (Table 3). The range of overrun was in the order of formulation $3 > 5 > 4 > 1 > 2$. Formulation consists of dairy ingredients (control) was significantly different from others. Nevertheless, there was no significant effect between T4 & T5 (dairy based formulations) as well as T1 & T2 (non-dairy based formulations) ($P > 0.05$). Tender coconut is an ideal source of solids-non-fat in formulating vegetarian ice cream. It was understood that the overrun was affected by different fat sources. Fat from coconut milk resulted in lower overrun. Though saturated fatty acids dominate in dairy milk fat and coconut fat their carbon chains are different. Dairy fatty acids are more of short and long chain, whereas coconut has medium chain. Fast digestibility and more resistant to oxidation are the major advantages of coconut fat. There was a slight reduction in overrun after replacing refined sugar with coconut sugar in dairy based ice cream (control). Coconut sugar might disrupt the foam capacity. But, interestingly, there was an improvement in overrun after the addition of tender coconut in addition to coconut sugar (T5). Choo et al. (2010) observed that ice cream made by replacing dairy milk fat with higher percentage of VCO (12%) resulted in the least amount of air incorporation than with lower percentage (4%). Overrun is generally ranges from 34 to 97% (Erkaya et al. 2012). Every 5% increase of amla pulp addition resulted in 4% reduction in overrun (Goraya and Bajwa 2015). Fuangpaiboon and Kijroongrojana (2017) obtained an over run of 23.74 to 35.70% in milk ice cream modified with fat replacers. Besides fat, protein content is also important for ice creams overrun, once it contributes to air interfaces stabilization (Turan et al. 1999). It is very clear from the data that additional of protein supplements increased the overrun. Positive effect of protein-based fat replacers on overrun was reported by Aykan et al. (2008). Emulsification ability of milk proteins can alter air cell interfaces of ice cream (Barfod et al. 1991).

Titratable acidity (%)

Titratable acidity of the ice cream mix in different formulations was ranged from 0.16% to 0.29% (Table 3) Formulations containing non-dairy ingredients showed significant influence on titratable acidity ($p < 0.01$). The results can be correlated with pH of ice cream mix as pH goes up as the titratable acidity goes down and vice-versa.

Acidity and pH are related to the composition of ice cream mix. Incorporation of processed amla caused significant ($p < 0.01$) raises in acidity and drop in pH due to the presence of ascorbic acid and phenolic substances in it. Besides, an increase in solids-non-fat raises the percentage acidity and lowers the pH. Higher acidity contributes to inferior flavour and adds to coagulation during pasteurization. However, the percent values obtained here were under the limit (0.3%) (Sukumar De 1991).

Quality evaluation of the ice cream

Crude fat (%)

Milk fat (including non-dairy sources) provides desirable flavour and helps to provide a good melting property as well as decrease the size of ice crystals. Moreover, fat also affects textural attributes such as viscosity, tenderness, elasticity, emulsification and ice crystallisation, and other desirable attributes such as richness and smoothness (Marshall and Arbuckle 1996). In addition, the destabilization of ice cream is affected by the melting point of the fats. Melting properties of fat is important. Melting resistance of ice cream produced from mix made with different fats decreased in the order of cream, vegetable fat and butter (Garti and Sato, 2001). Coconut fat has melting resistance but higher melting rate than ice cream formulated with whipping cream (Choo et al. 2010). Here, the result obtained for fat content of the ice cream ranged from 10.53% to % to 11.62% which fall in the category of medium fat ice cream. Typical ice cream contains at least 10% fat and a predetermined quantity of air (40 to 50% by volume). Statistical analysis revealed that the values were significant at 5% level. Non-dairy based formulations (T1 & T2) had significantly ($p < 0.05$) higher fat content than others. Negative correlation of percent fat content and overrun was observed from Table 3 and 4. It was also noted that 80% of the sample (5 g) from T1 and T2 melted during the melting resistance test carried out for 45 min (data did not include).

Crude protein (%)

Table 4 shows the effect of formulations on crude protein ($p < 0.01$). Crude protein content varied from 3.42% to 4.94%. The result was similar to that of total solids. Lower total solids and soluble solids content obtained in non-dairy based formulations (T1 & T2) were because of low protein content which affected the overrun. It shows that in non-dairy formulations, addition of some protein sources is needed for improving the quality. Conversely, all formulations had protein contents similar to the average protein found in the literature (ie, around 4%) (Arbuckle 1986; Erkaya et al. 2012).

Total sugars (%)

The total sugar content of the formulations varied from 10.56 to 11.34%. Formulations did not show any significant difference on the total sugar content ($P > 0.05\%$). A total sugar has mainly contributed by the added sugars mainly from coconut sugar and refined sugar. Results clearly indicated that, the addition of coconut milk and tender coconut did not contribute significantly on total sugars.

Total phenolics (mg/100 g)

Table 4 shows the total phenolic content in the five formulations which ranged from 19.70 mg/100 g to 38.0 mg/100 g. The effect of non-dairy ingredients on total phenolic content was highly significant. Among them, coconut based formulation (T2) consisting of coconut milk, tender coconut and coconut sugar resulted in the highest phenolic

Table 4 Quality evaluation of the ice cream

Ice cream mix Formulations	Moisture (%)*	TS (%)*	pH**	Density (g/cm3)**	TSS(°Brix)*ns	Titratable acidity (%)**	Over run (%)**
T1	67.28 ± 0.88^{a}	32.72 ± 0.88^{c}	5.95 ± 0.0^{b}	0.98 ± 0.0^{e}	24.75 ± 0.1	0.26 ± 0.01^{a}	46.39 ± 2.28^{c}
T2	67.26 ± 1.16^{ab}	32.74 ± 1.16^{bc}	5.90 ± 0.14^{b}	1.06 ± 0.01^{c}	22.55 ± 0.35	0.26 ± 0.02^{a}	40.00 ± 2.82^{c}
T3	63.00 ± 0.57^{ab}	37.00 ± 0.57^{bc}	6.47 ± 0.02^{a}	1.04 ± 0.01^{d}	25.50 ± 0.71	0.16 ± 0.01^{b}	86.00 ± 2.85^{a}
T4	62.80 ± 0.42^{bc}	37.20 ± 0.42^{ab}	6.30 ± 0.0^{a}	1.11 ± 0.0^{b}	26.80 ± 0.0	0.23 ± 0.05^{a}	72.50 ± 3.53^{b}
T5	58.50 ± 1.89^{c}	41.50 ± 1.89^{a}	6.35 ± 0.12^{a}	1.13 ± 0.0^{a}	29.40 ± 0.84	0.23 ± 0.02^{a}	74.00 ± 1.41^{b}

T1: Coconut milk with tender coconut (pulp and water) and refined sugar; T2: Coconut milk with tender coconut (pulp and water) and coconut sugar; T3: Dairy ice cream (control); T4: Dairy formulation with coconut sugar; T5: Dairy formulation with coconut sugar and tender coconut (pulp and water)

*ns non significant, *significant at 5%, **significant at 1%

[a, b, c]Different alphabets indicate that the values are statistically significant different from one another

content followed by T5, T1 and T4. Among coconut products, coconut milk had more effect on total phenolics than tender coconut and coconut sugar. The lowest phenolic content was observed in dairy based ice cream (control). Addition of ingredients such as frozen blueberry-soy dessert, kiwi juice and amla pulp had resulted in higher phenolic and antioxidant activity as compared to plain ice cream respectively (Teh et al. 2005, Sun-Waterhouse et al. 2013, Goraya and Bajwa 2015).

Ash content (%)

Ash content in the ice cream formulations ranged from 0.46% to 1.45%. Positive correlation of total solids and ash content is clearly visible from Tables 3 and 4. Higher ash content in T2 ($p < 0.01$) in comparison with T1 indicated the presence of mineral content in coconut sugar than refined sugar. Same was with the case of T3, T4 and T5. Control ice cream had the lowest ash content (0.46%) which was increased to 1.13% (ie, v 0.67% increase) after the addition of tender coconut and further to 1.45% (0.32% increase) after adding coconut sugar. Addition of strawberry pulp, fig paste, ginger shreds and juice, grape and mulberry pekmez in ice cream increased the ash content (Goraya and Bajwa 2015).

Sensory evaluation

Median value of the scores obtained for sensory attributes such as appearance, meltdown, fat feel, iciness and flavor & taste against the five formulations judged by panelist of different age groups is shown in Table 5. It is an interesting result as there was no difference on the sensory quality of ice cream formulations over different age category ($p > 0.05$). Significant effect was observed among the treatments consisting of different ice cream formulations ($p < 0.01$) which is a promising result of the experiment. The interaction effect of formulations and age group was found significant at 5%. Formulation 5 (T5) was preferred on the basis of its flavour, taste, meltdown, fat feel and

Table 5 Sensory evaluation of ice cream formulations

Formulations	Age Group	Appearance Median ± MD	Meltdown Median ± MD	Fat Feel Median ± MD	Iciness Median ± MD	Flavour & Taste Median ± MD
T1	Age (06–10)	6 ± 1.48	7 ± 1.48	6.5 ± 1.48	6 ± 1.48	6 ± 1.48
	Age (11–15)	6 ± 0.00	6 ± 1.48	6 ± 1.48	6 ± 1.48	7 ± 1.48
	Age (25–30)	7 ± 0.74	6 ± 0.74	6.5 ± 0.74	7 ± 0.00	8.5 ± 0.74
	Age (40–60)	8 ± 0.00	6.5 ± 0.74	8 ± 1.48	7 ± 0.00	9 ± 0.00
T2	Age (06–10)	8.5 ± 0.74	7 ± 0.74	6 ± 0.00	5 ± 1.48	4 ± 1.48
	Age (11–15)	6 ± 0.74	6 ± 0.74	6 ± 1.48	5.5 ± 1.48	6 ± 0.00
	Age (25–30)	7.5 ± 0.74	7 ± 1.48	6 ± 1.48	5 ± 1.48	7 ± 0.74
	Age (40–60)	6 ± 1.48	6 ± 1.48	6 ± 1.48	6 ± 0.74	6.5 ± 0.74
T3	Age (06–10)	8.5 ± 0.74	8 ± 1.48	8 ± 1.48	8.5 ± 0.74	9 ± 0.00
	Age (11–15)	8 ± 0.00	8 ± 0.74	7.5 ± 0.74	8 ± 0.00	8 ± 0.74
	Age (25–30)	8 ± 0.00	8 ± 0.00	7 ± 1.48	8 ± 1.48	5.5 ± 0.74
	Age (40–60)	7.5 ± 0.74	8 ± 0.00	5 ± 1.48	8 ± 0.74	7 ± 0.00
T4	Age (06–10)	8 ± 0.00	7.5 ± 0.74	8.5 ± 0.74	8 ± 0.74	9 ± 0.00
	Age (11–15)	7 ± 0.74	8 ± 1.48	7 ± 0.00	8 ± 0.00	8.5 ± 0.74
	Age (25–30)	6.5 ± 0.74	9 ± 0.00	6.5 ± 0.74	8 ± 1.48	9 ± 0.00
	Age (40–60)	7.5 ± 0.74	8 ± 0.74	8 ± 0.74	8 ± 1.48	8 ± 1.48
T5	Age (06–10)	8 ± 1.48	8 ± 0.74	8.5 ± 0.74	8 ± 0.74	9 ± 0.00
	Age (11–15)	7 ± 0.00	7 ± 0.00	7.5 ± 0.74	8 ± 0.00	9 ± 0.00
	Age (25–30)	6 ± 0.00	9 ± 0.00	6.5 ± 2.22	8 ± 1.48	9 ± 0.00
	Age (40–60)	8 ± 0.74	8 ± 0.00	8 ± 0.74	8 ± 1.48	8.5 ± 0.74

T1: Coconut milk with tender coconut (pulp and water) and refined sugar; T2: Coconut milk with tender coconut (pulp and water) and coconut sugar; T3: Dairy ice cream (control); T4: Dairy formulation with coconut sugar; T5: Dairy formulation with coconut sugar and tender coconut (pulp and water)

Effect of age group = Non-Significant at 5% level

Effect of formulations = Significant at 1% level

Age group x formulations = Significant at 5% level

Table 6 Comparison table of sensory attributes of different formulations (using Dunn test)

Comparison	Z	p– value (unadj)	p– value (adj)	Product	grouping letter
T1–T2	*1.890174*	5.87E–02	0.08390673	T1	x
T1 – T3	*–4.54292*	5.55E–06	1.10958E–05***	T2	x
T2 – T3	*–6.4331*	1.25E–10	6.25143E–10***	T3	y
T1 – T4	*–4.24298*	2.21E–05	3.67622E–05***	T4	y
T2 – T4	*–6.13315*	8.62E–10	2.87183E–09***	T5	y
T3 – T4	*0.299947*	7.64E–01	0.7642177		
T1 – T5	*–5.04623*	4.51E–07	1.12656E–06***		
T2– T5	*–6.9364*	4.02E–12	4.0222E–11***		
T3 – T5	*–0.5033*	6.15E–01	0.6830587		
T4 – T5	*–0.80325*	4.22E–01	0.5272895		

T1: Coconut milk with tender coconut (pulp and water) and refined sugar; T2: Coconut milk with tender coconut (pulp and water) and coconut sugar; T3: Dairy ice cream (control); T4: Dairy formulation with coconut sugar; T5: Dairy formulation with coconut sugar and tender coconut (pulp and water)

*** means significant at 0.1% level of significance

iciness; whereas formulation 4 (T4) was preferred with respect to its flavour, taste, meltdown, and iciness; and the control (T3) got preference in its appearance, meltdown and iciness. Furthermore, T1 acquired some positive rating with respect to flavour and taste and T2 obtained some positive rating in its appearance**.** Sanful (2009) reported that coconut milk in yogurt provided a creamy taste, smooth, and aromatic flavor. Fuangpaiboon and Kijroongrojana (2015) reported a sensory acceptance of coconut milk added with mixture of erythritol, inulin and fructose as a replacement to sucrose in ice cream with respect to firmness and meltdown intensities. Though the non-dairy formulations (T1 and T2) had lower solids, texture of the ice creams was finer. Further, the result obtained for the comparison of sensory attributes of different formulations using Dunn test carried out for Post hoc test (Table 6) revealed that T1 and T2 belong to same category (x), whereas, other products placed in other category (y) at 5% level of significance. The mean overall acceptance by the panelists according to product preferences is shown in Fig. S2 (supplementary) indicated that T3, T5 and T4 were highly accepted by the panelists.

Conclusion

The investigation was carried out to study the feasibility and effect of incorporating coconut milk, coconut sugar, tender coconut pulp and tender coconut water in ice cream. The formulations were made in such a way that the total solids and the fat content of the ice creams should be in the range of 30–40% and 10–12% respectively. Significant effects were observed in terms of physico-chemical quality of mix and ice cream most importantly the over run was affected by adding coconut ingredients. Though the dairy/control formulation was most accepted by the panelists, the coconut counterpart also have obtained acceptance in terms of appearance, flavour and taste. The quantity of the milk fat can also be increased and at the same time presence of soy or other protein supplements may improve flavour and texture of ice cream. Apart from that, increasing coconut milk and tender coconut pulp would give a significant amount of the functional compounds such as polyphenolics and antioxidants in the product. Incorporation of tender coconut and coconut sugar to dairy ice cream would also serve as a premium product. This investigation has provided a lead for developing an exclusive coconut based non-dairy ice cream. The positive attributes were good appearance better flavour and taste besides improvement in total phenolics and minerals. The drawback was the lower overrun and total solids as compared to the control, which could be corrected by addition of plant based protein sources. Enrichment of solid non-fat particularly with vegetarian sources or other bulking agents to the mix along with exclusive coconut ingredients on ice cream world definitely lead to a successful product with wide acceptability. Similarly, addition of tender coconut alone or tender coconut and coconut sugar in dairy based ice cream would result in better acceptability with functional and nutritional contents.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s13197-021-05279-y.

Acknowledgements The work was financially supported by the Coconut Development Board, Kochi. We are grateful to Dr. Anitha

Karun, Director of ICAR- CPCRI and the former Director, Dr. P. Chowdappa for the support and guidance.

Author contributions **SB** conceived the idea, planned & carried out the experiments and wrote the MS; **JPN** assisted in conducting the experiments, analyzing the qualitative attributes; **MMR** involved in planning of the experiment, supervision, and proof reading; **PR** involved in the conceptualization, manuscript editing and proof reading; **SS** contributed in statistical evaluation of data and its interpretation; **NS** involved in the standardization of qualitative parameters especially protein and ash; **HKB** supervised the work, guided in successful conduct of the experiments and supervision.

Funding The investigation was funded by Coconut Development Board (CDB), Kochi, Kerala.

Availability of data and material All data generated or analysed during this study are included in this published article.

Declarations

Conflicts of interest We (all the authors mentioned below the title) have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors declare that they have no competing interests.

Humans and animal rights The study does not involve any live animals or human.

References

Aboulfazli Baba1 AS F, Misran M. 2014. Effect of vegetable milks on the physical and rheological properties of ice cream. Food Sci Technol Res. 20 5 987 996

Ahsan TZ, Hussain M, Khalida N, Khaliqa A, Umar M (2015) Preparation and quality characterization of soy milk based non-dairy ice cream Int. J Food Allied Sci 1:21–27

Amal MH, Haleem A, Awad RA (2015) Some quality attributes of low fat ice cream substituted with hulless barley flour and barley ß-glucan. J Food Sci Technol 52:6425–6434

AOAC (1995) Official methods of analysis, 16th edn. Association of Official Analytical Chemists, Arlington

Arbuckle WS (1986) Ice cream, 4th edn. Van Nostrand Reinhold, New York

Aydar EF, Tutuncu S, Ozcelik B (2020) Plant-based milk substitutes: Bioactive compounds, conventional and novel processes, bioavailability studies, and health effects. J Funct Foods 70:103975.

Aykan Y, Sezgin E, Guzel-seydim ZB (2008) Use of fat replacers in the production of reduced-calorie vanilla ice cream. Eur J Lipid Sci Tech 110:516–520

Bajad DN, Kalyankar SD, Dehmukh MA, Bachanti PR, Bajad GS (2016) Impact of physico-chemical properties of mix on the final quality of ice-cream. Asian J Dairy & Food Res 35(4):293–297

Barfod NM, Krog N, Larsen G, Buchheim W (1991) Effects of emulsions on protein–fat interaction in ice cream nix during ageing. Quantitative analysis. Eur J Lipid Sci Tech 93:24–29

Bray HG, Thorpe WV (1954) Analysis of phenolic compounds of interest in metabolism. Methods Biochem Anal. :27–52. doi: https://doi.org/10.1002/9780470110171.ch2.

Chempakam B, Arivalagan M (2018) Biochemical and quality standards in processing and value addition of coconut, arecanut and cocoa. In: Manikantan MR, Chowdappa P (eds) Product diversification in Plantation. Today & Tomorrow's Printers and Publishers, New Delhi, pp 103–117

Choo SY, Leong SK, Henna Lu FS (2010) Physicochemical and sensory properties of ice-cream formulated with virgin coconut oil. Food Sci Technol Int 16:531–541

Erkaya T, Dağdemir E, Şengül M (2012) Influence of Cape gooseberry (Physalis peruviana L.) addition on the chemical and sensory characteristics and mineral concentrations of ice cream. Food Res Int 45:331–335

Fuangpaiboon N, Kijroongrojana K (2015) Qualities and sensory characteristics of coconut milk ice cream containing different low glycemic index (GI) sweetener blends. Int Food Res J 22:1138–1147

Fuangpaiboon N, Kijroongrojana K (2017) Sensorial and physical properties of coconut-milk ice cream modified with fat replacers. Maejo Int J Sci Tech 11:133–147

Garti N, Sato K. (2001). Crystallisation Processes in Fats and Lipid Systems. New York: CRC Press, pp. 329_351

Goff HD (1997) Colloidal aspects of ice cream—a review. Int Dairy J 7:363–373

Goff HD, Hartel RW (2013) Ice cream. Springer, New York

Goraya RK, Bajwa1 U (2015) Enhancing the functional properties and nutritional quality of ice cream with processed amla (Indian gooseberry) J Food Sci Technol. 52:7861–7871

Hebbar KB, Arivalagan M, Manikantan MR, Chowdappa P (2015) Coconut inflorescence sap and its value addition as sugar - collection techniques, yield, properties and market perspective. Curr Sci 109:1411

Junior ES, Lannes SCS. (2011). Effect of different sweetener blends and fat types on ice cream properties Ciênc. Tecnol. Aliment. Campinas, 31(1): 217–220X'

Lakshanasomya N, Danudol A, Ningnoi T (2011) Method performance study for total solids and total fat in coconut milk and products. J Food Compost Anal 24:650–655

Marshall RT, Arbuckle WS (1996) Ice Cream, 5th edn. Chapman and Hall, New york, p 349

Marshall RT, Goff HD, Hartel RW (2003) Ice Cream, 6th edn. Kluwer Academic Press, New york

McClements DJ, Newman E, McClements IF. (2019). Plant-based Milks: A review of the science underpinning their design, fabrication, and performance Compr. Rev. Food Sci. Food Saf. doi: https://doi.org/10.1111/1541-4337.12505, 0: 1–21.

Mehta BM. (2015) chemical composition of milk and milk products. In: Cheung P., Mehta B. (eds) Handbook of Food Chemistry. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-36605-5_31

Naresh kumar S, Hebbar, KB, Kasturi V, Rajagopal, V. (2018). Physiology and biochemistry. In: Nampoothiri KUK, Krishnakumar V, Thampan PK, Achuthan Nair M (Eds). The Coconut Plam (Cocos nucifera L.) Research and Development Prospectives. Springer, Singapore, pp 443–488

Ogle DH (2018). FSA: Fisheries Stock Analysis. R package version 0.8.19.

Onsaard E, Vittayanont M, Srigam S, D. Julian McClements DJ. (2006) Comparison of properties of oil-in-water emulsions stabilized by coconut cream proteins with those stabilized by whey protein isolate. Food Res Int 39:78–86

Patil U, Benjakul S. (2018). Coconut milk and coconut oil: their manufacture associated with protein functionality. J.Food Sci. 0:1–21

Pereira PC (2014) Milk nutritional composition and its role in human health. Nutrition 30:619–627

Philippine Coconut Authority (2004). What is Organic Coconut Sugar? www.natureblessings.com, Accessed 9 December 2019

Prapasuwannakul N, Boonchai S, Pengpengpit N (2014) Use of green coconut pulp as cream, milk, stabilizer and emulsifier replacer in germinated brown rice ice cream. Inter J Nutr Food Eng 8:462–465

Rethinam P, Bosco SJB (2006). Coconut- Harvest, processing and products. Asia & Pacific Coconut Community, Jakarta, Indonesia. pp36.

Salvatore Mangiafico (2018) rcompanion: Functions to Support Extension Education Program Evaluation. R package version 1.13.2. https://CRAN.R-project.org/package=rcompanion

Sanful RE (2009) Promotion of coconut in the production of yoghurt. African J Food Sci 3:147–149

Seow CC, Gwee CN (1997) Coconut milk: chemistry and technology. Int J Food Sci Technol 32:189–201

Silva PSA, Bamunuarachchi A (2009) Manufacture of carbonated tender coconut water and development of a process for the utilization of coconut flesh. AJOFAI 2:210–213

Sukumar De (1991) Outlines of Dairy technology. Oxford University Press. Pp. 182–224

Sun-Waterhouse D, Edmonds L, Wadhwa SS, Wibisono R (2013) Producing ice cream using a substantial amount of juice from kiwifruit with green, gold or red flesh. Food Res Int 50:647–656

Surapat S, Rugthavon P (2003) Use of modified starch as fat replacer in reduced fat coconut milk ice cream. Kasetsart J 37:484–492

Syed QA, Anwar S, Shukat R, Zahoor T (2018) Effects of different ingredients on texture of ice cream. J Nutr Health Food Eng 8(6):422–435. https://doi.org/10.15406/jnhfe.2018.08.00305

Tansakul A, Chaisawang P (2006) Thermo physical properties of coconut milk. J Food Eng 73:276–280

Teh YH, Dougherty MP, Camrie ME (2005) Frozen blueberry soy dessert quality. J Food Sci 70:119–122

Thimmaiah SK (1999) Standard method of biochemical analysis. Kalyani Publisher, New Delhi, pp 56–57

Turan S, Kirkland M, Trusty PA, Campbell I (1999) Interaction of fat and air in ice cream. Dairy Ind Int 64:27–31

U.S. National Library of Medicine (2020). Lactose intolerance. Genetics Home Reference. https://ghr.nlm.nih.gov/condition/lactoseintolerance.Accessed 1 October, 2020,

P Udabage M Annaugustin L Cheng PW Roderick Williams 2005 Physical behaviour of dairy ingredients during ice cream processing Le Lait, INRA Editions 85 4–5 383 394

Vanga SK, Raghavan V (2018) How well do plant based alternatives fare nutritionally compared to cow's milk? J Food Sci Technol 55:10–20

Wrage J, Burmester S, Kuballa J, Rohn S. (2019). Coconut sugar (Cocos nucifera L.): Production process, chemical characterization, and sensory properties. LWT - Food Sci.Technol. https://doi.org/10.1016/j.lwt.2019.05.125

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.