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Mohamed F. Y. Hassan
Haneen S. Alburaikan
Food Science and Human Nutrition Department
College of Agriculture and Food
Qassim University
Buraydah
51452
Saudi Arabia

Elsayed A. Mahmoud
Food Science and Nutrition Department
Faculty of Agriculture
Sohag University
Sohag
Egypt

Ateteallah Hassan Ateteallah
Mohamed F. Y. Hassan
Dairy Science Department
Faculty of Agriculture
Sohag University
Sohag
82524
Egypt

Corresponding author:
Ateteallah Hassan Ateteallah
ateteallah@agr.sohag.edu.eg

Chemical, nutritional, and sensory properties of ice cream incorporate varying amounts of Avocado (*Persea americana*) or Papaya (*Carica papaya*) fruit pulps

Mohamed F. Y. Hassan, Haneen S. Alburaikan, Elsayed A. Mahmoud and Ateteallah Hassan Ateteallah

Abstract

The purpose of this study was to examine the effects of incorporating up to 20% avocado pulp (AP) or papaya pulp (PP) into conventional ice cream (TC) on their chemical, rheological, nutritional, and sensory qualities. Substantial levels such as 10, 15, and 20% of prepared AP and PP were added to normal plan ice cream and manufactured following the commercial processing procedure. Results revealed that dry matter, especially SNF, increased significantly in both AP- and PP- ice cream. Accordingly, ash, fiber, and available carbohydrate contents were significantly increased, whereas the opposite result was recorded for crude protein due to AP and PP substitution. The instrumental color measurements of AP- and PP-ice cream indicated increasing AP or PP, considerably decreasing L*. PP-ice cream enhanced a* and b* more than AP-ice cream. The C value reduced dramatically in AP-ice cream and increased in PP-ice cream compared to TC. The ice cream containing 10 and 15% of AP or PP improved the overrun% and melting resistance rat, while high AP and PP contents had lower overrun% with higher melting resistance. Healthy phytochemicals like total carotenoids (TC), total flavonoids (TF), and total flavonols (TFL) were found in AP and PP-ice creams, demonstrating their properties. The AP and PP-ice cream had valuable total phenolic content (TPC) and high antioxidant capacity. However, only ice cream made with 10- 15% AP and PP was more highly accepted than others, compromising all characteristics. In conclusion, it is possible to use a substantial amount of AP and PP to produce up to 15% ice cream with retained natural color and unique TPC, carotenoids, TF, and TFL contents with valuable antioxidant capacity. The health-beneficial compounds and sensory acceptability of prepared ice cream formulas encouraged the commercial possibilities of using AP and PP to scale up further.

Keywords: Ice Cream; Avocado; Papaya; Nutritional Properties, Nutrition, Food supply, Antioxidant

INTRODUCTION

People are encouraged to progress and buy healthier products. The food business develops and labels "functional foods," or foods with bioactive components, to provide extra nutrients and health benefits (Villava *et al.*, 2017). However, dairy products' nutritional value and positive health impacts are linked to their regular consumption (Astrup, 2014; Thorning *et al.*, 2017). Ice cream is a popular dairy product (Elwood *et al.*, 2010) but lacks natural antioxidants, pigments, and bioactive phenolic compounds. Fruits and vegetables, which are strong in natural antioxidants and pigments, vitamins, low fat, and free from synthetic additives (Sun-Waterhouse, 2011a; Van Kleef *et al.*, 2002), as well as ice cream containing probiotics production (Cruz *et al.*, 2009), were all explored as potential ways to boost the ice cream's nutritional value. Processing ice cream encompasses blending, homogenization, pasteurization, cooling, aging, flavoring, coloring, whipping, packing, and hardening. The ingredients for typical ice cream are milk fat, milk solids-not-fat (SNF), sugar, water, stabilizers, emulsifiers, and liquid flavors and colors (Smith and Hui, 2008). When assessing an ice cream product and its accompanying processing, overrun and melting qualities are crucial (Arbuckle, 2013). Fruits and vegetables provide dietary fibers and polysaccharides with good physical characteristics and minimal effect on rheological properties (Soukoulis *et al.*, 2009) due to water-binding capacity (Tiwari *et al.*, 2015). People today are more mindful of eating and living healthy and will pay extra for nutritious food (Omar *et al.*, 2020). So, this study examined how adding nutritious fruits affects nutritional, physicochemical, and rheological qualities, whereas papaya and Avocado are rare for ice cream manufacturing. Avocado is one of the perishable fruits, and its benefits are abundant. Jimenez et al. (Jimenez *et al.*, 2021) recently mentioned that Avocado fruit has received particular attention in recent decades. Polyphenols, carotenoids, and tocopherols are found in avocado pulp, peel, seed, and leaves. These bioactive compounds can prevent and treat many diseases, which has piqued scientists' curiosity. Anticancer, antihypertensive, anticonvulsant, hypoglycemic, anti-inflammatory, antibacterial, and hepatoprotective properties were reported. Thus, avocado pulp and trash may include bioactive components for food or nutraceuticals. Clinical research shows that this species should constantly be included in our diets (Dreher *et al.*, 2021). Therefore, incorporating avocado fruits in different kinds of processing to increase consumption is recommended. One of the products that allow avocado fruit is an ice cream product because Avocado has a high fat content, so it is very suitable for making high-quality ice cream (Wijana *et al.*, 2001). Sirisoma (2004) revealed that incorporating avocado pulp (AP) into ice cream as a partial or complete replicant of dairy fat significantly improved overrun, melting rate, viscosity, and sensory attributes. The most popular was 50% avocado paste, which could replace dairy fat in ice cream (Surjawan and Abdillah, 2018). Similarly, Thepsuttinun (2012) formulated many ice cream formulas to produce low-fat ice cream and reduced the dairy fat content to 8.2% without affecting the physicochemical and rheological properties. Associatively, Khalil and Blassy (2015) suggested using up to 15% AP to make a low-fat ice cream with excellent antioxidant scavenging activity and good taste. Probiotic lactic acid bacteria were added to add more benefits to a non-dairy ice cream dessert based on Avocado. Ice cream was formulated; physicochemical properties and sensory characteristics were unaffected (Krawęcka *et al.*, 2021). In the most recent research of Moolwong et al. (2023), the AP was incorporated to produce low-fat ice cream. Replace milk fat with AP to lower moisture, protein, and fat and increase carbohydrate and crude fiber. Ice cream incorporating 20% AP was significantly increased total phenolic content, antioxidant capacity, and high overall acceptability. Papaya is a fruit of *Carica papaya* Linn., which belongs to the genus Carica. It is one of the native plants of Central America and is planted widely in most tropical and subtropical countries. Recently, it has received attention because of its nutritional and medicinal benefits, and most studies have focused on two applications: papaya fruit and papaya latex. Carbohydrates, vitamin C, vitamin A, copper, and magnesium are abundant (Bhargavi and Kusuma, 2017; Wall, 2006). Although other ice cream flavors are common, papaya is soft, sweet, and healthy, especially for kids who don't like papaya fruit (Bhargavi and Kusuma, 2017). The nutritional and therapeutic benefits of papaya have gained widespread recognition (Egbuonu, 2017; Kumar and PS, 2017). Patil et al. (2014) studied the effect of adding papaya pulp (PP) on the physicochemical characteristics and product cost. They stated that adding elevated levels of PP significantly decreased the total solids content, the protein content of ice cream, overrun, and the cost of production. However, the incorporation of 15% PP added nutraceuticals, created novelty, and increased quality and acceptability. Ali and El Zubeir (2023) concluded that adding PP significantly improved the chemical composition of camel milk ice cream. Papaya fruit is an important source of certain vitamins and minerals. Similarly, sensory evaluation procedures highly scored papaya ice cream's color, flavor, taste, and appearance with valuable nutritional value (Bhargavi and Kusuma, 2017). In addition, at 1.0 - 3.0%, papaya seeds have been incorporated into ice cream to enrich the total phenolic content and antioxidant activity. Acceptability of the ice cream was only affected with a higher seed ratio, while the physicochemical was not negatively affected (Omar *et al.*, 2020). In the same context, Hong et al. (Hong *et al.*, 2021) indicated that ice cream formulated with 20% (v/v) papaya puree might be suitable and more acceptable and marketable similarity indicated (Kumari *et al.*, 2014). Nothing was left; even papaya leaves were incorporated into ice cream production (Widjaja *et al.*, 2018). In recent years, published research has shown that tropical fruits are one of our society's new flavors and that fruit macro- and micro-nutrient compositions vary depending on many factors. Therefore, it was necessary to study the extent of acceptance and application of ice cream flavored with tropical fruits, e.g., papaya and Avocado, because they are new fruits to the Arabic Gulf region, e.g., Saudi society, and their use with different concentrations and preparations that have not been used before was targeted in this research. Thus, this research aimed to investigate the viability of developing a novel ice cream product incorporating different levels of papaya pulp (PP) and avocado pulp (AP) and assess their effects on nutritional, physicochemical, sensory, and some rheological properties

MATERIALS AND METHODS

1. Materials

Fresh milk contains 3% fat, freshly produced milk cream contains 33% fat, and dried skimmed milk contains 1.25% fat, 5% moisture, 6.75% minerals, 33% protein, and 54% lactose. These were obtained from El Marai Company, Al-Qassim, KSA. Sucrose, bovine gelatin, freshly harvested Avocado (*Persea americana*), and papaya fruits (*Carica papaya*) were purchased from the local market at Buraydah city, Al-Qassim region, KSA.

2. Avocado and Papaya pulps preparation

Ripe avocados were washed, dried, opened, flesh removed, and blended using a Braun Power Max MX 2000 blender (Brown, Germany), encapsulated in plastic bags, and cold stored at 4±1°C until use. The fruit's pulp is freshly prepared before making the ice cream (Khalil and Blassy, 2015).

3. Preparation of papaya fruit puree

The papaya fruit has been rinsed to remove dirt from its surface. The papaya peel was peeled using a peeler, and the seeds were removed with a spoon. The pulp was cut into smaller pieces with 5 x 4 x 3 cm dimensions. Fruit pieces were parboiled. The cut fruit pulp was put into a blender (Santos, VITA-MAX CORP-Light Industrial Food Preparing Machine Model, VM0122E, USA) and blended at 3 for 1 min until there was no noticeable solid form. The fruit's pulp is freshly prepared before making the ice cream (Hong *et al.*, 2021).

4. Ice cream preparation

According to Arbuckle (2013), the ice cream was made at Qassim University's Department of Food Science and Human Nutrition in the College of Agriculture and Veterinary Medicine based on the indicated ingredients in Table 1. To make the dry blend, dry milk powder and sugar were combined. They used a combination of fresh milk and cream to create the liquid. The liquid mixture was warmed to between 30 – 40 °C. The dry mixture was gradually added to the liquid mixture while stirring gently. Gelatin was dissolved in the right amount of water, stirred over a pot of boiling water, and then gradually added. The combination was combined for 1 minute using a mixer (Santos, VITA-MAX CORP-Light Industrial Food Preparing Machine Model, VM0122E, USA), pasteurized for 15 minutes at 80°C, chilled to 4°C, and AP and PP were added by substituting ~10, 15, and 20% from milk and cream ingredients. Table 1 shows that designed ice cream batches had 12% fat, 11% SNF, and 14% sugar with PP as sweeteners after estimating the sugar proportion in °Brix. Ice cream sweetness was equalized by eliminating AP and PP sugars from sucrose. The percentage of fat in the mixture was calculated by considering the percentage of fat in the Avocado after estimating the percentage of fat in the processed pulp. Pasteurized mixes were aged in the fridge at 4 °C for 20 h and whipped as frozen in a (Finamac, Pro 16, Made By Renan Florencio Correia Silva, Santo André, Brazil) at middle speed for 20 min. After collecting at -5°C, the ice cream was hardened at -18±1°C for 24 hours before analysis.

5. Proximate chemical analysis

Moisture, total solids, SNF, crude protein, fat, ash, crude fiber, and available carbohydrates were determined following standard methods of AOAC (2000).

Table 1. Different formulas of prepared ice cream supplemented with AP and PP amount per 100 g mix

Formulas	Milk 3% Fat	Cream 33% Fat	Dried milk (95% SNF)	Sugar	Gelatin	AP or PP
TC	50.25	30.15	5.1	14	0.5	0
10% AP	43.2	26.4	5.9	14	0.5	10
15% AP	40	24.2	6.3	14	0.5	15
20% AP	36	22.7	6.8	14	0.5	20
10% PP	39.5	30.8	6	13.2	0.5	10
15% PP	33.8	31.5	6.4	12.8	0.5	15
20% PP	28.38	31.9	6.82	12.4	0.5	20

TC: Typical control ice cream, AP: Avocado pulp, and PP: Papaya pulp

6. Instrumental color measurements of ice cream supplemented with AP and PP

Chromameters (ColorFlex; Reston, VA, USA) calibrated with standard white, green, and black tiles were used to take readings on the CIELAB-scale (L*, a*, b*) that were then used to determine the color of each sample. Color changes (E) and chroma (C) were computed relative to the values of the control sample according to Aljutaily et al. (2021) using the continuity equations [Eqn (1-2)]:

$C = (a^2 + b^2)^{0.5}$ ………………… (1);

$\Delta E^* = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{0.5}$………. (2)

7. The Overrun, Melting Time, and Melting Resistance

For the overrun and melting resistance evaluation, three batches of each type of ice cream were made: AP-ice cream, PP-ice cream, and TC-ice cream (Arbuckle, 2013; Schmidt, 2004). Overrun was calculated using the given equation: "% Overrun = (weight of mix used − weight of ice cream)/weight of ice cream × 100". Ice cream samples' melting time and resistance by melting 25 g at 22±1°C room temperature was measured. Dripping from samples on a narrow wire screen over a glass funnel was collected in a beaker. Melting time was recorded at the first drop. At 45 and 90 minutes, drainage weight was measured. We determined melting resistance by calculating the percentage of the relative melted amount per cycle (Muse and Hartel, 2004).

8. Phytochemicals and Antioxidant Activity:

8.1. Total Phenolic, Total carotenoid Contents and Antioxidant Activity

The TPC of prepared ice cream samples was determined using the Folin–Ciocalteu reagent according to an adapted method by Bettaieb et al. (2010). In brief, 150 µL of the sample was mixed with 300 µL of Folin-Ciocalteu reagent in Eppendorf tubes and agitated for 5 minutes. Subsequently, 300 µL of an alkaline solution (7.5% sodium carbonate solution, Na_2CO_3) was added to the mixture to arrest the reaction. The mixture was then incubated in the dark for 60 minutes at 25 °C, centrifuged on 10,000 × g for 10 minutes at 4°C, and 200 µL of supernatant from each Eppendorf was transferred to a new plate. The absorbance was measured at 760 nm using a microplate reader

(BioTek, Winooski, VT, USA), and the measurements were compared to the standard curve of gallic acid (GA) solution (R^2 = 0.99). TPC content per 100 g of dry weight (DW) was expressed as milligrams of gallic acid equivalents (mg GAE 100 g^{-1} DW). The total carotenoids (TC) were determined according to Yuan et al. (2009). TC concentration was measured at 450 nm and reported as mg g^{-1} dw. The DPPH-RSA as antioxidant activity (AOA) was assessed using the DPPH• assay (Alharbi *et al.*, 2022) at 517 nm. The antiradical activity was measured in Trolox Equivalents (TE) per gram (µmol TE 100 g^{-1}).

8.2. Determination of Total Flavonoids (TF) and Total Flavonols (TFL)

Based on Mohdaly et al. (2012), the TF content was determined for 60 min at 420 nm, and data were presented as mg Quercetin-Equivalent (QE) per 100 g^{-1} dw. According to Kumaran and Karunakaran's methodology (2007), TFL content was determined, and the optical density (OD) was measured after 150 min at 440 nm. The TFL concentrations were reported in mg of Quercetin-Equivalent (mg QE) per 100 g of dry weight (mg QE 100 g^{-1}).

9. Sensory Properties

The sensory characteristics of the formulations were tested after one day of freezing. Twelve well-trained staff members from the Food Science and Human Nutrition Department, College of Agriculture and Veterinary Medicine, Qassim University evaluated the AP and PP ice cream. The flavor, texture, melting, color, and appearance were given a maximum score of 40, 30, 10, 10, and 10, respectively, while the total acceptance was expressed as the summation of all attributes. Consequently, all panelists were asked to evaluate the presented sample with unknown codes. After statistical analysis, the attributes' mean values and standard errors were averaged (Arbuckle, 2013).

10. Statistical Analysis

Triplicates of all analyses were performed. SPSS 23 (IBM, USA) was used for statistical analysis at a 0.05 significance level. Following Steel et al. (1997), Tukey's multiple-range test was used to conduct the one-way ANOVA for the experimental design and comparisons.

RESULTS

1. Effect of AP and PP Addition on Approximate Chemical Composition

Table 2 shows the chemical composition of prepared TC, AP, and PP ice creams. The AP- and PP- ice cream formulas were significantly characterized by increased dry matter concentration, especially SNF ($P < 0.05$). The PP increased the dry matter more than the AP. Similarly, significant increases in ash and carbohydrates were recorded due to adding AP and PP compared to the TC-ice cream sample, and the increase was even more incredible when PP was added. However, substituting AP or PP for fresh milk significantly reduced crude protein. However, results showed that adding AP or PP had no significant effect on the fat content between all treatments.

Table 2. Chemical composition and relative energy value of ice creams supplemented with AP and PP (Mean ± SE), *n*=3.

Component (%)	Ice cream formulas						
	TC	AP 10%	AP 15%	AP 20%	PP 10%	PP 15%	PP 20%
Total solid (TS)	37.57 ±0.01^{g}	38.14 ±0.01^{f}	38.46 ±0.03^{e}	39.25 ±0.03^{c}	38.76 ±0.02^{d}	39.90 ±0.01^{b}	40.20 ±0.03^{a}
SNF	25.51 ±0.10^{f}	25.91 ±0.04^{e}	26.19 ±0.12^{d}	26.98 ±0.06^{b}	26.56 ±0.05^{c}	27.67 ±0.02^{a}	27.90 ±0.13^{a}
Crude protein	4.29 ±0.02^{a}	3.92 ±0.01^{b}	3.79 ±0.02^{c}	3.64 ±0.02^{d}	3.90 ±0.01^{b}	3.76 ±0.01^{c}	3.60 ±0.01^{d}
Fat	12.07 ±0.09^{a}	12.23 ±0.03^{a}	12.27 ±0.09^{a}	12.27 ±0.09^{a}	12.20 ±0.06^{a}	12.23 ±0.03^{a}	12.30 ±0.12^{a}
Ash	0.79 ±0.01^{e}	0.93 ±0.01^{d}	0.99 ±0.01^{b}	1.02 ±0.01^{a}	0.96 ±0.01^{c}	0.96 ±0.01^{c}	1.01 ±0.01^{ab}
Available carbohydrates	20.42 ±0.08^{g}	21.06 ±0.02^{f}	21.41 ±0.13^{e}	22.32 ±0.08^{c}	21.70 ±0.05^{d}	22.95 ±0.01^{b}	23.29 ±0.14^{a}

TC: typical control ice cream, AP: Avocado pulp, PP: Papaya pulp, SNF: sold not fat, ^{a,b,c,d,e,f,g}: No significant difference (P>0.05) between any two means within the same raw have the same superscripted letters.

2. Effect of AP and PP Addition on Color Parameters

The results of the instrumental and visual color measurements of prepared AP-ice cream and PP-ice cream are illustrated in Table 3. As expected, adding PP enhanced the redness and yellowness, while the AP slightly decreased the redness and increased the greenness values compared to TC. The L* value was significantly decreased with increasing AP or PP levels. The a* and b* values were increased better in PP ice cream than in AP ice cream. The C value significantly decreased in AP-ice cream and increased in PP-ice cream compared to TC ice cream. The delta E value significantly decreased with the increase in the AP and PP levels.

Table 3. Instrumental color analysis ice creams supplemented with AP and PP (mean±SE), *n*=3.

Parameters	Ice cream formulas						
	TC	10% AP	15% AP	20% AP	10% PP	15% PP	20% PP
*L**	92.18 ±0.19[a]	83.85 ±0.16[b]	78.76 ±0.15[d]	66.28 ±0.13[f]	82.14 ±0.33[c]	74.85 ±0.28[e]	65.15 ±0.41[g]
*a**	-4.46 ±0.29[f]	-3.23 ±0.05[e]	-2.83 ±0.31[e]	-0.55 ±0.10[d]	0.83 ±0.18[c]	15.73 ±0.44[b]	26.84 ±0.66[a]
*b**	5.44 ±0.27[d]	4.47 ±0.24[de]	3.95 ±0.22[e]	3.49 ±0.19[e]	17.21 ±0.56[c]	26.42 ±0.48[b]	28.99 ±0.70[a]
C	6.32 ±0.26[d]	6.32 ±0.38[d]	4.87 ±0.36[de]	3.53 ±0.19[e]	17.24 ±0.55[c]	30.75 ±0.63[b]	39.51 ±0.96[a]
Delta E	00±00[e]	87.85 ±0.21[a]	82.59 ±0.19[b]	69.93 ±0.15[d]	87.29 ±0.44[a]	83.10 ±0.47[b]	77.29 ±0.80[c]

[a,b,c, d,e,f,g]: There is no statistically significant difference when comparing means in the same column with the same superscript (P>0.05). letters

3. Effect of AP and PP Addition on Rheological Parameters

Figure 1 depicts the overrun of both the AP and PP ice creams after manufacturing. Overrun of AP and PP-ice creams were 39.29 - 66.10 % and 40.54 - 65.77%, respectively. The overrun increased with the addition of both AP and PP at 10%, but it subsequently presented a dramatic decrease with increasing AP or PP by more than 15% and up to 20%. Increasing AP at 10 and 15% was obviously better than PP at 10-15% in improving the overrun %.

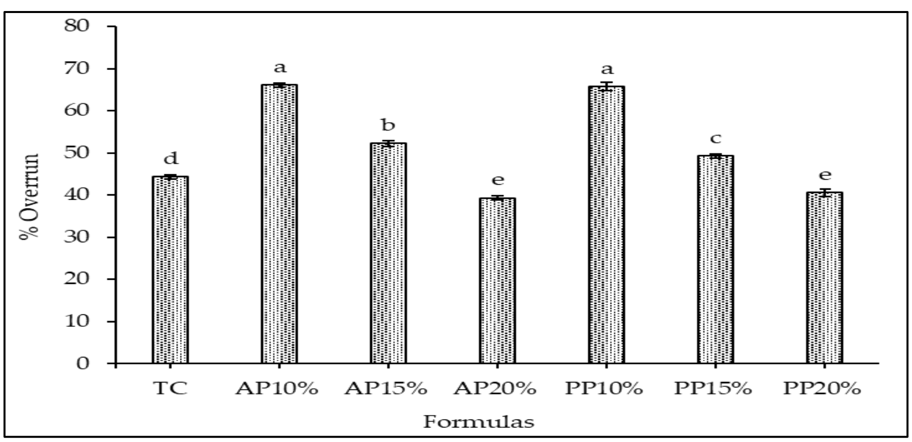

Figure 1. The overrun % of prepared ice cream formulas incorporated AP and PP (Mean ± SE), *n*=3. [a,b,c,d,e]: Bars not sharing similar letters significantly differ (*P*>0.05).

Figure 2 shows the average values of the resistance to melting, expressed in time per minute for the first drop of ice cream to fall for the different treatments. The time needed for the mixture's first drop to fall at a temperature of 22 °C was used to calculate the melting point. The first treatment was TC, which took 31.67 min for the first drop to fall, while the most extensive time for that was in ice cream with a higher level of AP, where the first drop descended after 44.33 min.

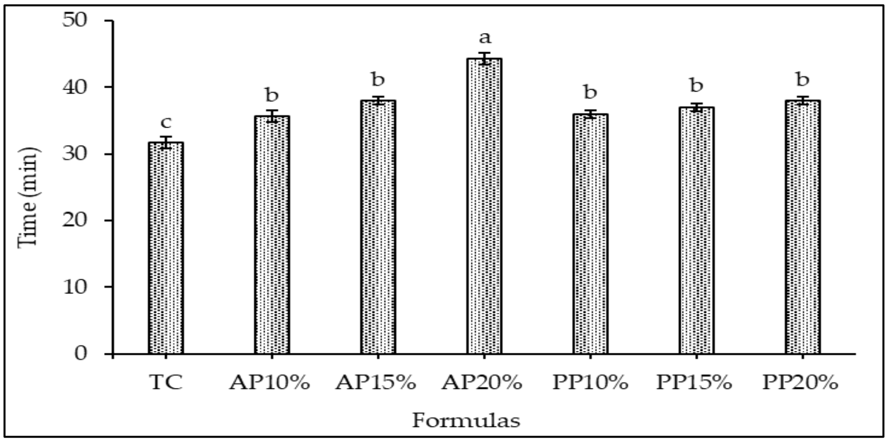

Figure 2. Melting time of prepared ice cream incorporated AP and PP (Mean ± SE), *n*=3. [a,b,c]: Bars not sharing similar letters significantly differ (P>0.05).

Figure 3 shows the difference between AP and PP ice cream in their resistance to melting. After 45 minutes, the TC-ice cream samples had the most significant percentage of weight loss compared to the other ice cream recipes (P 0.05). Also, there was an enormous loss after 90 minutes for the control sample of TC-ice cream. The result from Figure 3. also showed a slight decrease in Weight loss % of the ice cream as the inclusion level of fruit increased, which indicates a higher melting resistance, as the more added samples showed a more excellent melting resistance with 20% AP.

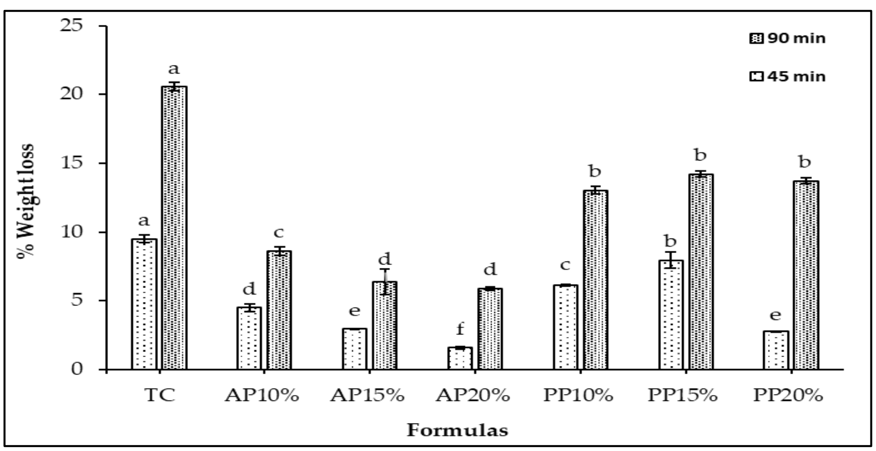

Figure 3. Melting resistance of prepared ice cream formulas incorporated AP and PP after 45 and 90 min, respectively (Mean ± SE), *n*=3. [a,b,c,d,e,f]: Bars not sharing similar letters are significantly different (P>0.05).

4. Effect of AP and PP Addition on Phytochemicals and the antioxidant capacity

The TPC, TC, TF, and TFL contents, as well as AOA using DPPH radicals scavenging activity of ice creams incorporated 10, 15, and 20% AP or PP, are shown in Table 4. Increasing the amounts of AP and PP led to a steady rise in TPC concentration. The TPC level ranged from 211.39 mg GAE g^{-1} dw in 10% PP-ice cream to 391.38 mg GAE g^{-1} dw in 20% AP-ice cream when compared to TC-ice cream (158.01 mg GAE g^{-1} dw). TPC levels in AP-ice cream were significantly higher than in PP-ice and TC-ice cream. The TC content was not detected in TC-ice cream, while TC in PP-ice cream ranged from 6.39 mg 100 g^{-1} dw in 10% AP to 9.99 mg 100 g^{-1} dw in 20% AP and in PP-ice cream from 9.21 mg 100 g^{-1} dw in 10% PP to 15.96 mg 100 g^{-1} dw in 20%PP. Regarding the AOA, scavenging activity against DPPH radicals rose significantly with increasing AP or PP substitution levels, as shown in 10% AP-ice cream (153.25 μmol TE 100 g^{-1} dw). The TF content ranged from 8.89 to 16.99 mg QE 100 g^{-1} dw in AP-ice cream and from 6.28 to 13.11 mg QE 100 g^{-1} dw in PP-ice cream. TFL content in AP-ice creams varied from 4.32 to 7.98 mg QE 100 g^{-1} dw, while PP-ice creams had a lower range of 2.19 to 5.98 mg QE 100 g^{-1} dw.

Table 4. Phytochemicals composition and antioxidant activity of ice creams supplemented with AP and PP (Mean ±SE), *n*=3.

Component (%)	Ice cream formulas						
	TC	10%AP	15%AP	20%AP	10% PP	15% PP	20% PP
Total Phenolic content [mg GAE 100 g^{-1}]	158.01 [a] ±5.38	238.38 [c] ±3.25	314.36 [e] ±5.14	391.38 [g] ±9.19	211.39 [b] ±6.43	298.38 [d] ±6.28	375.11 [f] ±7.01
Carotenoids [mg 100 g^{-1}]	0.00 [a] ±0.00	6.39 [b] ±0.9	8.28 [c] ±1.21	9.99 [c] ±1.31	9.21 [c] ±2.1	13.15 [d] ±1.27	15.96 [e] ±1.38
DPPH [μmol TE 100 g^{-1}]	0.00 [a] ±0.00	153.25 [e] ±6.25	178.13 [f] ±7.59	200.28 [g] ±10.12	98.31 [b] ±3.19	125.28 [c] ±5.47	135.58 [d] ±4.25
Total flavonoid [mg QE 100 g^{-1}]	0.00 [a] ±0.00	8.89 [c] ±1.13	13.97 [e] ±1.25	16.99 [f] ±1.68	6.28 [b] ±1.09	9.59 [d] ±1.28	13.11 [e] ±1.39
Total flavonols [mg QE 100 g^{-1}]	0.00 [a] ±0.00	4.32 [b] ±0.25	5.89 [c] ±0.78	7.98 [d] ±0.79	2.19 [b] ±0.28	4.02 [b] ±0.87	5.98 [c] ±0.99

TC: typical control ice cream, AP: avocado pulp, and PP: papaya pulp, a,b,c,d,e,f, g: There is no statistically significant difference (P>0.05) between any two means that share the identical raw data and get the same superscript letter.

5. Effect of AP and PP Addition on Sensory Properties

Table 5 shows the average values of the sensory attributions for samples of different ice cream treatments manufactured by sensory different percentages of AP and PP. It shows the values of appearance, color, flavor, texture, melting, and overall acceptability. The results show no significant difference between the treatment appearance and the control sample, but adding 20% AP led to a significant decrease in appearance (8.08). The 20% PP gave the highest color value (9.33), while the sample 20% AP gave the lowest value (8.67). Also, the 20% PP gave the highest evaluation in flavor (38.33), the lowest value for the sample was 20% AP (24.67), and the lowest value for the sample 20% AP, was significant relative to the TC. The results in Table 5 also indicated no significant differences in texture between the control sample and all treatments. The control sample recorded the highest degree of texture (28.33), followed by a sample of 10% AP (28.25), and the lowest treatment in terms of texture was 20% PP (26.42). Table 5 shows the average values of sensory attributions for the melting properties of ice cream samples for different treatments, where there was a significant difference between the treatment of 10% AP (9.50) and all of the treatments. The overall acceptability of the different treatments is the final judgment on the quality of the product. The results showed a high overall acceptability of the treatment, 10% AP (92.75), while the treatment of 20% AP recorded the lowest level in terms of overall acceptability (76.58).

Table 5. Sensory properties of prepared ice cream formulas supplemented with AP and PP (Mean ±SE), *n*=3.

Sensory parameters	Ice cream formulas						
	TC	10% AP	15% AP	20% AP	10% PP	15% PP	20% PP
Appearance	9.33 ±0.28[a]	9.17 ±0.27[a]	9.25 ±0.25[a]	8.08 ±0.36[b]	9.42 ±0.29[a]	9.25 ±0.22[a]	9.00 ±0.41[a]
Color	9.17 ±0.30[a]	9.25 ±0.25[a]	8.83 ±0.34[a]	8.67 ±0.19[a]	9.08 ±0.31[a]	9.25 ±0.30[a]	9.33 ±0.31[a]
Flavor	36.17 ±0.56[ab]	36.58 ±0.78[ab]	35.08 ±1.18[b]	24.67 ±1.59[c]	36.08 ±0.80[ab]	38.08 ±0.61[a]	38.33 ±0.53[a]
Texture	28.33 ±0.58[a]	28.25 ±0.57[a]	27.92 ±0.61[a]	26.75 ±0.57[a]	28.17 ±0.61[a]	26.58 ±1.06[a]	26.42 ±1.03[a]
Melting	9.25 ±0.25[ab]	9.50 ±0.19[a]	9.33 ±0.31[ab]	8.42 ±0.31[b]	9.33 ±0.36[ab]	9.08 ±0.40[ab]	9.08 ±0.45[ab]
Overall acceptability	92.25 ±1.34[a]	92.75 ±1.52[a]	90.42 ±1.43[a]	76.58 ±1.88[b]	92.08 ±1.39[a]	92.25 ±1.67[a]	92.17 ±1.95[a]

TC: typical control ice cream, AP: avocado pulp, and PP: papaya pulp, [a, b, c]: No statistically significant difference (P>0.05) between any two means that share identical raw data and get the same superscript letter.

DISCUSSION

Customers first judge ice cream by its color and appearance, then picture its taste and health benefits to decide if they'll consume it again. Eating nutritious, tasty ice cream requires a pleasing color and taste. The macro- and micronutrient contents of fruits vary depending on numerous conditions and recently published research has demonstrated that tropical fruits are one of our society's new flavors. Since tropical fruits like papaya and Avocado are relatively novel to the Arabic Gulf region (e.g., Saudi society), it was important to investigate how widely consumed and utilized these flavors in ice cream, particularly when combined with other previously unexplored ingredients and preparations. In addition, tropical fruits like papaya, kiwifruit, Avocado, and mango boost immunity and enhance health benefits. These fruits contain valuable phytochemical content that may prevent cancer, depression, ulcers, and dandruff and activate the immune system (Kalt *et al.*, 1999; Lija and Beevy, 2021). Therefore, the current study aimed to prepare nutritious ice creams by incorporating a substantial amount of PP and AP to present various applicable products for consumers' demand. The chemical composition of AP and PP-ice creams was noticeably altered when 10 - 20% PP or AP were added. As AP and PP levels increased, the dry matter concentration, especially SNF, significantly increased even when PP increased the dry matter higher than AP. Subsequently, the ash and carbohydrate levels were the predominant nutrients that increased due to adding AP and PP compared to the TC-ice cream sample (Hong *et al.*, 2021; Khalil and Blassy, 2015; Krawęcka *et al.*, 2021; Moolwong *et al.*, 2023; Sirisoma, 2004). On the contrary, significant decreases in crude protein were found due to fresh milk being replaced with AP or PP. However, results showed that adding AP or PP had no significant effect on the fat content between all treatments. This may be due to adding AP and PP, which are rich in carbohydrates and ash contents and low in proteins compared to basic ice cream ingredients (Khalil and Blassy, 2015; Krawęcka *et al.*, 2021; Moolwong *et al.*, 2023; Sirisoma, 2004; Surjawan and Abdillah, 2018). The L* values of ice creams were reduced due to the components, like fruits, fruit juice(s), and phenolic extracts, added to boost functionality and improve sensory characteristics (Öztürk *et al.*, 2018; Sakr *et al.*, 2023). The TC and the 10% AP were found to have the highest L* value, while the 15% and 20% PP had the lowest. Because of their dissimilar morphologies, AP and PP fruits have significantly different L* values. Significant differences were detected between the b* values of TC and all treatments; the b* value of 20% AP was lower than these samples. As expected, adding Papaya fruit pulp enhanced the redness and yellowness, while the supplementation of Avocado fruit pulp slightly decreased the redness value compared to the control. All ice cream treatments showed a significant ($p \leq 0.05$) increase in redness and yellowness; chroma (C) decreased with the increase added Avocado concentration but increased with the increase of papaya concentration. Delta E decreased with the increase in the concentration of fruit pulp. The ice cream was changed in color because of different pigments and phytoconstituents found in the pulp, as similarly mentioned (Goraya and Bajwa, 2015; Hassan and Barakat, 2018; Sakr *et al.*, 2023). Regarding physicochemical properties, overrun increased with the addition of Avocado and papaya. Still, it showed a decrease with an increase in the added concentration until it reached the lowest level at a concentration of 20%, and it was less than the control. These findings suggested that a more than 20% increase in PP could significantly impact the overrun. The ice cream mix's fat, milk-SNF, and solid content influence the overrun (Smith and Hui, 2008). The ice creams used in this research had a reasonable 12 % fat level. More aggregated fat droplets mean a greater overrun because they can trap a phenomenal number of air bubbles in the ice cream (Arbuckle, 2013). Overrun levels can vary depending on how milk proteins interact with other components on the air-cell interfaces of ice cream due to differences in emulsification ability, such as the amphiphilic feature (Schmidt, 2004). Lack of creaminess and smoothness arises from exceptionally low overrun, which suggests little air has been introduced, giving a chilling sensation in the mouth. Contrarily, even though some nations set 100% as the legal overrun limit for ice cream, a large overrun makes the ice cream foamy (Sun-Waterhouse, 2011b). Similarly, moderate jambolan pulp concentrations improved the overrun% due to presented pectic substances and low fiber content, while increasing the concentration will affect the matrix when high fiber and pectic substances were interfered (Soares *et al.*, 2018). In the same context, the resistance to melting expressed in time per minute for the first drop of ice cream is an important test to evaluate the melting behavior during the handling. The time needed for the mixture's first drop to fall at a temperature of 22 °C was used to calculate the melting point. The highest melting resistance increased associatively with high AP and PP concentrations. Multiple variables were identified to affect ice cream's hardness and melting resistance, including ice crystal size, ice crystal quantity, overflow, the degree of fat instability, and the rheological qualities of the mix **(**Hassan and Barakat, 2018**;** Moolwong *et al.*, 2023**;** Omar *et al.*, 2020**;** Sakr *et al.*, 2023**;** Surjawan and Abdillah, 2018**).** Conversely, adding AP and PP will maximize the health benefits compared to TC-ice creams, as shown in TPC, TC, TF, and TFL, as well as the AOA of prepared fruit-ice creams. The phytochemicals and AOA increased with the AP or PP concentrations. There was a significant increase in the TPC, TC, TF, and TFL content of ice cream made with AP and PP compared to TC-ice cream, suggesting that using PP in milk products is beneficial (Fayed, 2015; Nguyen and Hwang, 2016; Yu *et al.*, 2014). Those extractable phytochemicals enhance the ice cream's beneficial characteristics. Even the avocado and papaya polyphenols that form complexes with ice cream components like milk proteins and polysaccharides during mixing and/or aging processing have the potential to be scaled up further (Arts *et al.*, 2002). AP and PP ice creams' antioxidant activity was more remarkable than TC ice creams. Incorporating AP and PP may have increased the ice cream's antioxidant activity because of their high phytochemical content. Previous research has also reported similar results (Hassan and Barakat, 2018; Krawęcka *et al.*, 2021; Moolwong *et al.*, 2023; Nguyen and Hwang, 2016; Surjawan and Abdillah, 2018). Evaluation of a product based on the sense impressions it creates in the minds of its target market is known as sensory evaluation. The color, flavor, texture, melting, and overall acceptability of ice cream were significantly affected by increasing amounts of added AP and PP. One of the most important things people notice about ice cream is its flavor (Abdullah *et al.*, 2003). The size, number, and arrangement of the ice cream's air cells, ice crystals, lactose crystals, and fat globules determine its texture. The smoothness can be attributed to the consistency of tiny ice crystals and air cells (Öztürk *et al.*, 2018; Sakr *et al.*, 2023). When the air cells are very large or numerous, a snowy texture develops, and other textural flaws, such as (mucilaginous, fragmentation, coagulation, watery, and so on), manifest themselves in the ice cream, typically as a result of inaccuracy in the mixture formulas (Webb and Johnson, 1965). Akoh and Decker (Akoh and Decker, 1995) emphasized that the perceived viscosity of the particles in their melted state is a crucial aspect in determining how the ice cream sample would feel in the mouth. The overall acceptability of the different treatments is the final judgment on the quality of the product. The results concluded that the treatments had a high overall acceptability for 10% AP and 10-20% PP, as all levels are accepted.

CONCLUSION

A notable characteristic of the AP and PP ice creams was an increased dry matter content, primarily in SNF. When PP and AP were swapped out, the amount of ash, fiber, and accessible carbs increased significantly, while crude protein decreased. Ice creams with higher AP and PP concentrations have better melting resistance and overrun %. The AP and PP ice creams had healthy ingredients, including TC, TF, and TFL. Ice creams produced with PP and AP had the highest total polyphenol content and antioxidant capacity. We only got positive feedback for the ice cream, including 15% AP and PP. To summarize, ice cream with 15% AP and PP can have its natural colors intact, unique TPC, TC, TF, and TFL, and great antioxidant capacity. Because the produced ice cream formulae were both aesthetically pleasing and chemically helpful, the commercial potential of using AP and PP for scaling up was high.

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