THE EFFECTS OF PUMPKIN AND RED SWEET POTATO ON PHYSICO-CHEMICAL PROPERTIES AND SENSORY ACCEPTANCE OF THE FRESH PLANT-BASED ICE CREAM

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ABSTRACT

With the rise in healthy diets and growing concerns about the environment and health, plant-based ice cream has become attractive to those who want to avoid animal products, food synthetic preservatives and additives. Recently, carbohydrates have been used as stabilizers to create gel structures and retain large amounts of free water in the food system. This study aimed to investigate the impact of pumpkin (PP), red sweet potato (SP), and their mixture on the physicochemical properties and sensory acceptance of plant-based ice cream prepared with a base of liquid obtained during the cooking of Lima beans (called aquafaba) and coconut milk. The recipe for the fresh plant-based ice cream mixture (% wt. of aquafaba) was as follows: sugar 20%; citrus fiber 1%; coconut milk powder 12%; coconut oil 6%; vanilla 0.6%. Four different formulas, which included the addition of 35% of PP (PP35), 35% of SP (SP35) and 35% of a mixture (M35) of PP and SP in a 1:1 ratio (by wt.), and a control sample (CS) with no addition were examined for cream viscosity, overrun (OR), water holding capacity (WHC), texture properties, melting rate and sensory evaluation. The results showed that, due to the advantages of both PP and SP, the ice cream M35 had the lowest melting rate with the dripping loss significantly reduced by 43-45% (%wt.) compared to PP35 and SP35. Besides, the sensory evaluation score of M35 was the highest, so M35 was considered the optimal supplement formula. This study contributes to the use of natural emulsion stabilizers in plant-based ice cream.

Keywords: Melting rate, natural emulsion stabilizers, pumpkin, red sweet potato, plant-based ice cream.

1. INTRODUCTION

Ice cream is a frozen aerated emulsion (oil in water) that contains partially coalesced fat globules, air bubbles, ice crystals, and unfrozen viscous serum. It also includes high molecular weight polysaccharides, mineral salts, proteins, and water [1]. Ice cream is a popular frozen milk dessert that is widely produced and consumed worldwide. In recent years, there has been increasing attention towards healthy food options. Plant-based ice cream, also known as dairy-free ice cream, offers a low-fat alternative that is suitable for healthy diets. However, removing or reducing fat from ice cream can result in disruptions to the fat globule network and changes in product quality. Fat plays a crucial role in emulsion production, ice crystal size and shape, and melting time in ice cream. To address these issues, many fat substitutes are used in ice cream formulations to minimize defects caused by reduced fat content. Fat substitutes are substances that mimic the physical and sensory properties of fats in food while providing fewer calories.

These substitutes are typically classified into lipids, proteins, and carbohydrates. Starches, in particular, are essential fat substitutes used in ice cream production as thickeners and stabilizers. They work by forming a gel structure and retaining a significant amount of free water [2].

The term "Aquafaba" is derived from two Latin words: "Aqua" meaning water and "faba" meaning beans [3]. It refers to the liquid obtained during the cooking of beans, which contains various nutrients such as proteins, simple sugars, polysaccharides, minerals, and phytochemical compounds including saponins and phenolic compounds. These components contribute to the function of aquafaba, including its foaming, emulsifying, gelling, and thickening properties. Due to these characteristics, aquafaba can be used as a vegan, gluten-free, and cholesterol-free rheological additive in various food products. It can serve as a substitute for eggs and milk in mayonnaise, whipped cream, ice cream, emulsified sauces, cocktails, and baked goods [4].

Pumpkin (Cucurbita) is a potential source of bioactive compounds such as polyphenols, carotenoids, tocopherols, sterols, bioactive proteins, peptides, dietary fiber, pre-and probiotics, and fatty acids. These compounds make it a suitable ingredient for producing healthy, low-fat foods [5]. Sweet potato (Ipomoea batatas [L.] Lam) belongs to the Convolvulaceae plant family. SP is particularly rich in protein, fiber, B vitamins, β-carotene, and minerals like iron, calcium, magnesium, and zinc. Sweet potatoes also contain other bioactive compounds [6]. Pumpkin (PP) and red sweet potato (SP) are ideal carbohydrate sources that can act as natural stabilizers in plant-based ice cream made from aquafaba and coconut milk powder.

Recently, there has been growing interest in the development of plant-based ice cream. The use of milk substitutes poses various technological and sensory challenges. To address this, researchers have explored the use of plant-based milk blends that incorporate strong soy and sesame proteins to produce plant-based ice cream with desired texture and sensory properties. These approaches have resulted in ice cream samples that achieve overrun retention values comparable to typical ice cream samples. Additionally, the hardness and consistency of plant-based ice cream are higher than those of conventional ice cream [7]. Furthermore, a novel plant-based ice cream has been produced using gluten- and lactose-free plant-based yoghurt as the main ingredient [8].

Besides, the use of natural plant-based stabilizers for milk-based or plant-based ice cream is also a topic that researchers are paying much attention to. Stabilizers are a group of ingredients that can enhance viscosity and stability during temperature changes, improve texture, slow down the melting rate, and prevent moisture loss during the preservation of ice cream. Additionally, they can control the amount of air incorporated into the ice cream during production and help create a stable foam [9]. In a study, fibers such as psyllium and pectin fibers were used as complete replacements for conventional stabilizers to enhance the rheological, textural, and sensory properties of plant-based milk ice creams (such as almond milk and hemp milk) [10]. Another study demonstrated that using chia seed mucilage as a stabilizer in ice cream resulted in a decrease in overrun and melting rate as the concentration of chia seed extract in the ice cream formulation increased [11]. Similarly, the addition of PP to ice cream was shown to slow down the melting rate [12]. Furthermore, citrus fiber improved the structural and physical properties of free-milk ice cream made from lima bean aquafaba, coconut milk, and purple sweet potato [13]. In that study, two types of citrus fibers, namely 100M40 and 300FG, were used to create the ice cream's structure. The results indicated that compared to samples using 100M40 citrus fiber, samples using 300FG citrus fiber exhibited higher overrun and reduced firmness. However, ice cream models using 300FG citrus fiber had a faster melting rate compared to samples using 100M40 citrus fiber. Though the study incorporated purple sweet potato as an ingredient, it solely focused on the citrus fiber content, without mentioning the carbohydrate content of the purple sweet potato. This article will provide clarification on the impact of adding carbohydrate ingredients from PP and SP to plant-based ice cream in the study.

The physical and sensory properties of ice cream are influenced by microstructural factors. While ice (phase volume and crystal size distribution) and air (gas incorporation and retention, gas cell size distribution) are often considered key structural elements, ice cream also contains a complex fatty phase that can affect its texture and sensory attributes. The fat globules in ice cream can either remain intact after freezing, maintaining the same size and distribution, or partially recombine to form larger, unstable fat clusters. The melting properties of ice cream are influenced by these microstructural factors from both a mechanical and sensory perspective. Due to the complexity of these microstructural elements, the process of ice cream melting is quite intricate. Alternatively, heat transfers from the warmer environment into the ice cream mass at a rate regulated by microstructural factors [14]. The trend of eating to protect the environment is increasing, so research on the structural properties of fresh vegetable ice cream made from aquafaba solution and coconut milk with the addition of red sweet potatoes or pumpkin is a research direction that deserves attention. The study was conducted with the following research contents: 1) Effect of PP and SP on the properties and stability of the ice cream solution mixture; overrun, hardness and melting rate of ice cream 2) Sensory evaluation of ice cream formulations.

2. MATERIALS AND METHODS

2.1. Materials

All agricultural ingredients were sourced from Vietnam. Lima beans were purchased at Duc Trong farmers market in Lam Dong, Da Lat. The chemical composition of Lima beans was described as protein 30.83 ± 8.17, lipid 14.77 ± 0.99; total ash 4.44 ± 0.11; moisture 12.39 ± 0.25 (% wt.). The basic nutritional composition of red sweet potato as moisture 25.46 ± 2.70, starch 15.84 ± 2.16, protein 1.91 ± 0.32, lipid 2.77 ± 0.12, crude fiber 1.96 ± 0.45, and total ash 2.21 ± 0.45 (% wt.). The nutritional composition of PP was moisture 82.78 ± 0.03, protein 6.83 ± 0.16, lipid 7.35 ± 0.22; total ash 2.04 ± 0.87, crude fiber 0.94 ± 0.14; carbohydrates 1.95 ± 0.71 (% wt.).

The flavouring and texture additives were derived as follows: Coconut milk powder was a product of Asia Saigon Food Ingredients Joint Stock Company, located at Lot C-9E-CN, My Phuoc 3 Industrial Park, Thoi Hoa Ward, Ben Cat Town, Binh Duong Province, Vietnam. Vietcoco Organic Coconut Oil was produced by Luong Quoi Coconut Processing Co., Ltd., with the address Lot A36-A37, An Hiep Industrial Park, Thuan Dien hamlet, An Hiep commune, Chau Thanh district, Ben Tre province. Refined sugar was a product of TTC Bien Hoa - Dong Nai Sugar Co., Ltd. Citrus Fiber CF 300FG (abbreviated CF) was supplied by Asia Shine Light Company. The Vanilla used was a 500 ml/bottle from the manufacturer Healthy Food Brands Ltd., with the address Woodyard House Daux Road, Billingshurst West Sussex, RH14 5SJ, United Kingdom.

2.2. Preparation of ice cream

Step 1: Preparation of Aquafaba, Pumpkin (PP), and Red sweet potato (SP)

To prepare water-cooking Lima bean (aquafaba), the process described by Nguyen [15] was used: the beans were soaked in clean water for 8 to 10 hours and then cooked (using the Sanaky SNK-2018HG infrared) in a stainless-steel pot with a ratio of beans to the water of 1:5 (w/w). The pot was covered and cooked until boiling using a 2000W power setting; then the power was reduced to 400W. The cooking time for the beans was approximately 45 minutes. After cooking, the mixture was filtered through a sieve to remove any bean residue, dirt, and tiny particles. Once filtered, the aquafaba was stored in a zip bag and frozen at -4°C. Preparation of SP and PP: They were peeled, and then the seeds were removed from the PP. SP and PP were then washed and cut into slices with a thickness of 1-1.2 cm, and 200g was steamed by a steamer (Bear DZG-C60Q8, 220V 50Hz, 650W) for 25 minutes. 20 g of boiling water was mixed with 10g of coconut powder to obtain coconut milk. The coconut milk was stored in the refrigerator.

Step 2: Preparation of the ice cream mixture

The ingredient proportions of the ice cream are provided in Table 1. Aquafaba (kept at a temperature of 12±2℃) and either SP or PP were placed in a mixer and blended for 1 minute. Sugar and CF were added to a blender (WMF KULT X Mix & Go, 300W, Germany) and blended for 40 seconds. Coconut oil was slowly added and the mixture was blended for another 40 seconds. When the mixture reached a temperature of 25±1℃, the coconut milk and vanilla flavour were slowly added, and blended for an additional 40 seconds.

Step 3: Making the ice cream

The prepared mixture was poured into an ice cream machine (UNOLD 48818, 150W, Germany) and the Ice Cream mode was selected. The mixture was allowed to churn for 60 minutes per batch.

2.3. The formulation for the mixture of fresh plant-based ice cream

Table 1. The formulation for the mixture of fresh plant-based ice cream

Ingredients	Aquafaba	Sugar	CF	Coconut milk powder	Coconut oil	Vanilla flavour	PP	SP
CS	150gr	20%	1%	12%	6%	0.6%	-	-
PP35							35%	-
SP35							-	35%
M35							17.5%	17.5%

Note: % by wt. of aquafaba. CS: the control sample; PP: Pumpkin; SP: Red sweet potato;
M: mixture (M35) of PP and SP in a 1:1 ratio (by wt.)

2.4. Determination of overrun (OR) of the ice cream

The overrun (OR) refers to the amount of air that is incorporated into ice cream during the freezing process. OR of ice cream was analyzed according to the method of Khosrow et al. (2021). The OR value was determined by using the formula [16]:

$$\%\,OR = \frac{(m\ mixture\ of\ ice\ cream) - (m\ ice\ cream)\ 100}{m\ ice\ cream}$$

Where m $_{\text{mixture of ice cream}}$ poured into an ice cream machine and m $_{\text{ice cream}}$ was the mass of the obtained product with the same unit volume

2.5. Determination of water holding capacity

Water holding capacity (WHC) was identified based on the published model with minor adjustments [17]. Samples were centrifuged at 6000 rpm for 20 min and at 25°C (see Figure 1-a) and then the WHC was determined by the formula:

$$\%\,WHC = \frac{(W_0 - W)}{W_0} \times 100$$

Where: W_0 and W are the weight of foam emulsions in a 10 ml centrifuge tube and gel weight in a centrifuge tube after removing excess water, respectively.

2.6. Determination of viscosity (Viscosity, η)

The viscosity of the cream solution was determined using a viscometer (Brookfield DV-III Ultra, USA) with slight modifications [18]. The apparent viscosity of the emulsion samples was measured at 25°C using spindle 63 (see Figure 1-b). Viscosity measurements were taken at increasing shear rates ranging from 0 to $140s^{-1}$. The viscosity of the emulsion was recorded specifically at a shear rate of $120s^{-1}$.

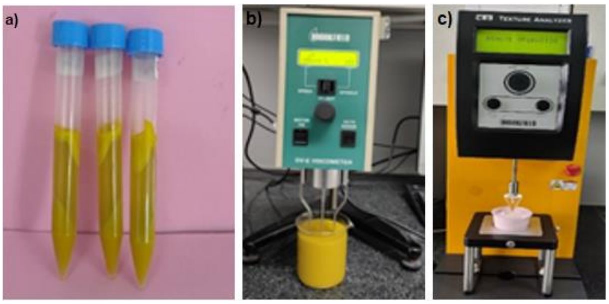

Figure 1. a) Centrifuge tubes with separated water, b) the equipment used for determination of viscosity, c) the instrument used for the determination of structural properties of the ice cream.

2.7. Determination of texture properties of the ice cream

The structure analysis of the ice cream was conducted according to Shahi et al. (2021) [16] with slight adjustments: The ice cream samples were placed in the freezer overnight at -25°C before measurement. For the penetration test, a texture analyzer (CT3 Texture Analyzer, Brookfield, USA) equipped with a conical probe (45 °C) and a 10g force sensor was used at room temperature (see Figure 1-c). The penetration depth and speed were set at 10 mm and 2 mm/s, respectively. The hardness (HR) (in grams) was recorded.

2.8. Determination of the melting rate of the ice cream

The melting rate of the ice cream was assessed following the methodology outlined by Shahi (2021) with minor modifications. Ice cream samples weighing 80 ± 2g were placed in round beakers and stored in a freezer at -20°C for 24 hours. The measurement of the melting rate was conducted at room temperature (23 ± 2°C), and the ice cream samples were positioned on a wire mesh (3mm x 3mm) (see Figure 2). The weight of the melted material was recorded at 10-minute intervals for 80 minutes [16].

Figure 2. Illustration of an experiment to examine the melting rate of ice cream

2.9. Sensory evaluation method

The sensory evaluation of the ice cream products was conducted based on Borrin's model (2018). Each ice cream recipe was assigned a unique code consisting of three different 3-digit numbers. A panel of 40 untrained individuals participated in the evaluation. The sensory parameters assessed included fatness (which plays a crucial role in the taste and structural characteristics of ice cream), smoothness (indicating the texture and palatability of ice cream, with lower ice crystal formation preferred), melting (an important criterion for assessing ice cream quality), as well as colour, odour, taste, and flavour.

The sensory evaluation was performed on a scale ranging from 1 to 7, representing different levels of acceptability for each sensory indicator of each sample. The scale included highly disliked, immensely disliked, disliked, no opinion, like, exceedingly like, and highly likeable. Due to the nature of ice cream, samples would melt if left at room temperature, which could affect their organoleptic properties. To prevent this, the research team brought each coded ice cream sample from the freezer and served them to the volunteers one at a time. Additional samples were provided as needed until all samples were tested and evaluated [19].

2.10. Data analysis

Each experiment was set up in a randomized design with three replications, and the data are reported as Mean ± SD. The analysis of variance (ANOVA) was conducted using a one-factor method, and any significant differences between treatments were determined using the Least Significant Difference (LSD) test at a significance level of $\alpha = 0.05$, with Statgraphics Centurion XV.I software. Graphs were created using Microsoft Excel 2016 software.

3. RESULTS AND DISCUSSION

3.1. Effect of PP and SP on the WHC and viscosity of the ice cream mixture

Ice cream mixtures are gel emulsions [20], also known as emulsion-filled gels. Texture characteristics play a crucial role in determining the quality of gel foods, including WHC, viscosity, gel strength, and microstructure. WHC, as well as gel strength (texture), are essential properties of gel emulsions. WHC refers to the ability of a protein to bind water, and it is positively correlated to the storage modulus of emulsion gels [21]. Emulsion gels with higher storage modulus tend to have a denser and more uniform microstructure, allowing them to retain water molecules even under vigorous centrifugation [17].

Table 2. Water holding capacity and viscosity of the ice cream mixtures.

Sample	%WHC	η (cP)
CS	$79.25^{b} \pm 0.57$	$334.67^{ab} \pm 16.04$
PP35	$75.82^{a} \pm 0.48$	$464.67^{b} \pm 19.55$
SP35	$79.55^{b} \pm 0.10$	$3307.00^{d} \pm 289.58$
M35	$75.51^{a} \pm 0.94$	$736.67^{c} \pm 144.80$

Values are expressed as Mean ± SD; different letters a, b, c, d, and e represent the difference of the means in the same column with statistical significance level P-value < 0.05

Based on the data from Table 2, it can be observed that the CS and the SP35 samples had the highest WHC with almost no significant difference ($79.25^{b} \pm 0.57$; $79.55^{b} \pm 0.10$). It was worth noting that the SP35 sample had the highest viscosity among the surveyed samples (10 times higher than the CS). This could be explained according to the report of Zhang et al. (2019) who suggested that sweet potatoes contain high inulin content, it contributed to increasing the viscosity in the solution [22]. Besides, Sweet Potato is a food crop rich in carbohydrates [6], in which inulin, starch and fiber have been recognised as substances capable of replacing fat and improving the physicochemical and sensory properties of the cream [23]. The CS did not have any additional ingredients added, so it had the lowest viscosity. Samples PP35 and M35 showed low and similar water retention values. However, sample M35 had a higher viscosity (736.67c ± 144.80) due to the presence of soluble fiber from PP (17.5%), which also contributed to WHC [12]. The addition of inulin-containing SP, as mentioned earlier, further enhanced the viscosity of the mixture in the M35 sample.

3.2. Effects of PP and SP on the properties of OR and HR of ice cream

Many factors influence the properties of ice cream. Overrun (OR) belongs to the microscopic structure of the cream, which is related to the distribution of air cells and is considered one of the main factor affecting structure along with ice (phase volume, crystal size distribution) [14]. Stabilizer content and type, ice crystal content, and emulsifier level and style all impact the microstructure of ice cream, ultimately affecting its melting characteristics [24]. The CS had the lowest OR ($4.88^a \pm 0.04$) since it relied solely on the foaming ability of the aquafaba solution without the addition of SP or PP (see Table 3).

Table 3. Effects of PP and SP on the properties of overrun and hardness of ice cream

Sample	Overrun (OR, %)	Hardness (HR, g)
CS	$4.88^a \pm 0.04$	$1199.17^a \pm 95.16$
PP35	$19.59^d \pm 0.09$	$4791.00^c \pm 688.14$
SP35	$15.13^b \pm 1.07$	$3413.17^b \pm 335.20$
M35	$16.73^c \pm 0.16$	$3945.67^{bc} \pm 582.05$

Values are expressed as Mean ± SD; different letters a, b, c, d, and e represent the difference of the means in the same column with statistical significance level P-value < 0.05

The ice cream PP35 had the highest OR ($19.59^d \pm 0.09$). It can be explained by the fact that PP had a much higher fat and protein content than sweet potatoes. Fat and protein were considered surfactants, so they have a better gas-holding effect and have the highest OR. In addition, PP was rich in protein and fat, so it increased the ability to emulsify and create gel, thus positively affecting the texture properties of ice cream [25]. On the other hand, SP was richer in fiber, so its ability to retain gas in the fibrous networks was poorer. This inconsistency may be attributed to the high viscosity of the ice cream mixture with too many SP ingredients, which hindered vigorous stirring and air incorporation during the freezing process. A similar effect was observed when adding excessive xanthan gum to the ice cream mixture [2]. Therefore, it can be concluded that PP was more effective than SP in enhancing the gas retention of ice cream. It should also be noted that the SP35 had a lower OR than the PP35 but was still higher than the CS. This result was obvious because the CS did not have any additional ingredients, so the properties of the cream were poor.

Regarding the relationship between OR and HR, the results showed some correlation, particularly in the PP35 sample with the highest OR and HR values. In the CS, both OR and HR scores were the lowest. This suggests that ice cream with higher overrun tends to exhibit higher hardness. However, the HR of ice cream is influenced by various factors, including gas incorporation and retention, ice crystal size, volume of ice phase, and fat stability [26]. An explanation can be found in the density of ice cream, as increased density leads to reduced aeration and increased firmness [27]. This finding aligns with the observation that adding mashed PP can increase the firmness of ice cream [28].

3.3. Effects of PP and SP on the melting rate of ice cream

The degree of fat instability, the viscosity of the mixture, and the overrun have an impact on the melting process. The addition of a stabilizer increases the viscosity of the ice cream mixture. As the ice crystals melt, the water dilutes the serum phase, and gravity governs the melted ice cream. A viscous emulsion slows down drainage, resulting in a slower decomposition rate. Additionally, increased emulsion viscosity leads to higher shear forces during freezing, which promotes interactions between fat globules and instability. Consequently, during melting, large fat globules collide and jam together to prevent further drainage. Moreover, the amount of air affects heat conduction and influences the melting speed of the ice cream because air acts as an insulator, preventing heat penetration [24].

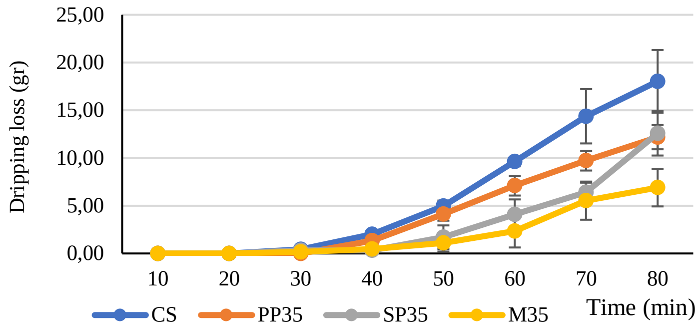

Figure 3. Effects of PP and SP on the melting rate of ice cream

Figure 3 illustrated the melting rate of the CS and the samples supplemented with SP and PP, measured by the weight of melted ice cream (in grams) per unit of time (in minutes). In the first 30 minutes, both the CS and SP35 samples showed no weight change in the dripping loss. However, the CS exhibited a significantly larger amount of melted ice cream compared to the others, as indicated by the high slope of the CS curve, whereas the line representing the M35 sample had the lowest, which showed that mixing PP and SP reduced the dripping loss of ice cream. After 80 minutes, the PP35 and the SP35 samples had the same melting rate values, 12.18±1.27 and 12.58±2.32 g, respectively. For the sample M35, due to the combined advantages of both PP and SP, the melting rate of this sample was generally lower compared to the samples with only SP or PP. After 80 minutes, the amount of melted ice cream in the M35 sample was the lowest compared to the two samples only added SP or PP, the dripping loss was significantly reduced by 43-45%. It is worth noting that starch is used as a fat substitute in ice cream to increase its viscosity [29, 30]. Since SP is a starch ingredient [31], it can be concluded that the low melting speed of SP ice cream was mainly due to the high starch content in sweet potatoes, leading to a higher viscosity of the ice cream, making it more difficult to melt. When combining SP and PP in the cream mixture, there was the presence of starch, soluble and insoluble fiber and citrus fiber (with the same ratio in the mixing formulation). These polysaccharides could stabilize emulsions, making it harder for ice cream to melt. This issue will be explained more clearly in section 3.4.

3.4. Sensory evaluation

For the CS, the observed colour was milky white compared to other samples; due to the addition of both PP and SP which had a yellow-orange colour. The colour of a food is an essential visual factor in determining its taste. Therefore, it can be seen that the samples with the addition of PP or sweet potato all had a higher colour acceptance score than that of the CS (Table 4); this was explained by the fact that red, orange, and yellow colour ranges increased arousal and craving for food [32].

The aroma and fragrance of different foods are influenced by the smells of their respective ingredients. While the CS ice cream sample had a pure vanilla and bean scent, the PP ice cream sample, in addition to those scents, also carried a distinct PP aroma, similar to the other ice cream samples. However, individual preferences for specific aromas can vary [33]. Therefore, this indicator should be considered as a subjective reference.

Sweetness is a crucial aspect of cold dessert products like ice cream [34]. Although the same amount of sugar was added to each formula, there were variations in the acceptable levels of sweetness and aftertaste, especially when comparing the CS with the other three variants.

This difference can be explained by the inherent sugar content present in PP and SP, which increased the overall sweetness of the ice cream and resulted in a higher level of acceptance.

Table 4. The results of sensory acceptance

Sensory properties	CS	PP35	SP35	M35
Colour	$4.33^{a} \pm 0.84$	$5.55^{b} \pm 1.35$	$5.50^{b} \pm 0.90$	$5.45^{b} \pm 0.73$
Aroma	$4.35^{a} \pm 0.84$	$4.98^{b} \pm 0.88$	$5.38^{bc} \pm 0.91$	$5.55^{c} \pm 0.20$
Sweetness	$4.73^{a} \pm 1.17$	$5.50^{b} \pm 1.54$	$5.45^{b} \pm 0.36$	$5.33^{b} \pm 0.72$
Sweet aftertaste	$4.78^{a} \pm 0.08$	$4.90^{a} \pm 0.47$	$5.28^{ab} \pm 1.50$	$5.53^{b} \pm 0.00$
Fatness	$4.13^{a} \pm 0.40$	$5.25^{b} \pm 0.24$	$5.40^{b} \pm 1.04$	$5.43^{b} \pm 0.22$
Smoothness	$3.78^{a} \pm 0.94$	$5.30^{b} \pm 0.59$	$5.40^{b} \pm 0.90$	$5.35^{b} \pm 0.78$
Melting rate	$3.90^{a} \pm 0.81$	$5.65^{c} \pm 1.26$	$5.08^{b} \pm 1.13$	$5.75^{c} \pm 2.06$

Values are expressed as Mean ± SD; different letters a, b, c, d, and e represent the difference of the means in the same row with statistical significance level P-value < 0.05

The fat content, smoothness, and melting rate were heavily emphasized. Except for the CS, the other variants received high acceptance scores for fat content (as shown in Table 4). Both the ice cream of PP35 and SP35 exhibited smoother textures and higher levels of melting resistance compared to the control sample. This result can be explained as follows: PP is rich in soluble and insoluble fibers [35], and both PP and SP are known to be high-fiber ingredients [36]. Fiber plays a crucial role in stabilizing the emulsion system of ice cream [37], preventing the formation of ice crystals and enhancing smoothness, richness, and texture. Consequently, the melting resistance of the ice cream was improved.

4. CONCLUSION

In this study, PP and SP demonstrated their advantages in improving the texture of plant-based fresh ice cream. The ice cream SP35 had 10 times higher viscosity and equivalent WHC to the CS sample, while the PP35 showed high spillability and hardness. Ice cream samples with higher OR tended to exhibit higher hardness. PP35 supplement cream had better microscopic properties such as OR and hardness, but the cream had a relatively low melting point (only better than CS) compared to other ice cream samples. M35 was only inferior to PP35 in terms of OR while hardness could be considered the same. M35 was considered the optimal formula, with the highest melting and sensory scores compared to other supplement formulations.

Further research is needed to study the appropriate mixing ratio between PP and SP so that the resulting ice cream has the desired melting level. Other agricultural ingredients and alternatives to aquafaba can also be sought to achieve even better results in the production of environmentally friendly vegetable ice cream products.

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TÓM TẮT

ẢNH HƯỞNG CỦA BÍ ĐỎ VÀ KHOAI LANG ĐỎ ĐẾN CÁC TÍNH CHẤT HÓA LÝ VÀ CẢM QUAN CỦA KEM TƯƠI THỰC VẬT

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Với sự gia tăng về chế độ ăn uống lành mạnh, mối quan tâm ngày càng cao về môi trường và sức khỏe, kem làm từ thực vật đã trở nên hấp dẫn đối với những người muốn tránh các sản phẩm động vật, chất bảo quản, phụ gia và chất màu tổng hợp. Gần đây, carbohydrate được chứng minh có thể sử dụng để thay thế chất ổn định do khả năng hình thành cấu trúc gel và giữ một lượng lớn nước tự do bên trong hệ thống thực phẩm. Nghiên cứu này nhằm mục đích khảo sát ảnh hưởng của bí đỏ (PP), khoai lang đỏ (SP) và hỗn hợp của chúng lên các đặc tính hóa lý và sự chấp nhận cảm quan của kem làm từ thực vật được chế biến bằng chất lỏng thu được trong quá trình nấu đậu ngự (gọi là aquafaba) và bột sữa dừa. Công thức làm hỗn hợp kem làm từ thực vật tươi (% khối lượng aquafaba) như sau: đường 20%; chất xơ CF 1%; bột sữa dừa 12%; dầu dừa 6%; vani 0,6%. Thành phần bí đỏ hoặc khoai lang đỏ và mẫu kem kết hợp cả hai (tỷ lệ 1:1) được cho vào mẫu kem theo tỉ lệ (35%), mẫu đối chứng (0%) và tiến hành khảo sát thời gian tan chảy của kem giữa các công thức trong cùng một điều kiện. Các thuộc tính cấu trúc khác của kem lạnh như độ nhớt của hỗn hợp dịch kem, khả năng kết hợp và giữ khí của kem, cấu trúc, và giá trị cảm quan của kem lạnh trong từng mẫu kem đã được khảo sát. Kết quả cho thấy kem được bổ sung bí đỏ có OR và độ cứng cao nhưng độ tan chảy của kem tương đối thấp. Do ưu điểm của cả bí đỏ và khoai lang đỏ nên mẫu kem M35 có tốc độ tan chảy thấp nhất, với độ thất thoát nhỏ giọt giảm đáng kể từ 43-45% khối lượng so với các mẫu kem chỉ sử dụng bí đỏ hay khoai lang đỏ. Bên cạnh đó, điểm đánh giá cảm quan của kem bổ sung M35 lại cao nhất nên M35 được xem là công thức bổ sung tối ưu. Nghiên cứu này góp phần vào xu hướng sử dụng các chất ổn định nhũ tương tự nhiên có nguồn gốc từ thực vật cho kem tươi từ thực vật.

Keywords: Bí đỏ, cacbohydrate, chất ổn định tự nhiên, độ tan chảy của kem, kem thực vật, khoai lang đỏ.