Short Research Article
Development of a Novel Recipe for Vegan Ice Cream Based on Brown Rice Milk

Comment [U1]: Modify this way: Recipe for brown rice milk-based vegan ice cream

ABSTRACT

The market for plant-based proteins, particularly alternatives to dairy products, is growing due to health benefits and environmental concerns. Many people are adopting plant-based diets, due to intoleranceor vegan and vegetarian lifestyles; thus, promoting lactose-free and cholesterol-free alternatives to milk-derived products such as ice cream. Rice, which is a lactose and gluten free product, as well as low in fat, and calories, could be a promising substitute for dairy milk in foods such as ice cream. In the current study, the development of a novel recipe for ice cream based on brown rice milk was investigated. After standardizing the rice milk production protocol, six combinations of hydrocolloids were used as emulsifiers, as well as four sweeteners for granulated sugar substitution were tested. In all formulations, meltdown and overrun parameters were measured and at the final stage organoleptic evaluation was conducted to determine the level of sensory panel acceptance. In conclusion, it wasevitable that the rice milk-based ice cream, which combines xanthan gum, guar gum, k-carrageenan, with 30% sugar substitution with stevia, was the formulation with the highest acceptance in the physiological characteristics and sensory evaluation.

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Keywords:*hydrocolloids; panelists; plant based; lactose free; sugar; sweetener.*

1. INTRODUCTION

Nowadays, reports have highlighted significant growth in the market for plant-based proteins, particularly in new alternatives to traditional meat and dairy products, which besides have significant environmental footprints [1, 2]. The trend of adopting a plant-based diet is increasing especially in Western countries, with many choosing to substitute animal products for vegetable options [3]. Besides intolerances, vegan and vegetarian lifestyles are also promoting plant-based alternatives to natural milk-derived dairy products, citing the benefits of lactose-free, cholesterol-free, and low-calorie foods that are better for overall health, including preventing lactose intolerance and cow's milk allergy [4]. While ice cream is a popular frozen dairy product with a great taste and texture, it has high levels of fat and cholesterol, which can be harmful to human health [5]. Additionally, lactose in ice cream can cause lactose intolerance among lactase-deficient consumers [6]. As a result, many consumers have shifted towards dairy-free ice cream. However, producing plant-based ice cream is a technological challenge because milk and dairy ingredients give ice cream its unique flavor and structure [7]. Hence, there has been growing interest in creating new food alternatives to traditional dairy-based products with plant-based substitutes such as rice. Individuals allergic to wheat-related crops (barley, oats, rye) often can tolerate rice and reactions to rice are rare in Europe and America. Thus, rice could be a promising substitute for dairy milk in foods such as ice creams, since it is lactose-free, low in fat, and low in calories.

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The quality of the final ice cream can be evaluated by several parameters such as melting and overrun.The meltdown rate of ice cream is influenced by various factors such as the quantity of air incorporated, the ice crystal nature, and the network of fat globules formed during freezing. Sakurai et al.,[8] discovered that ice creams with lower overruns melted quickly, while those with high overruns had a slower meltdown rate and better melting resistance. The slower melting rate in ice creams with high overruns was due to reduced heat transfer resulting from a larger volume of air, but it could also be attributed to the more complex path through which the melting fluid must flow [9]. Decreased hardness in ice cream is caused by lower overruns (and consequently larger ice crystals) [10], whereas the presence of air (high overrun percentage) decreases ice cream hardness [11]. As a result, contradictory findings on the relationship between air content and hardness in ice cream have been observed, possibly due to differences in secondary effects such as ice crystals. Pelan et al., [12] discovered that it is the air cell stability that slows down the meltdown rate of ice cream, as established by adding saturated monoglycerides to the mix. Campbell and Pelan [13] discovered that melt-down resistance increased as the draw temperature from the freezer decreased due to increased overrun and fat destabilization, although ice crystals may also have influenced the meltdown rate.
The aim of the current study is to develop a lactose and gluten-free ice cream based on rice milk, suitable for lactose intolerant and vegan people, using natural additives derived from fruits and vegetables. This rice ice cream (RIC) product should meet the standards of conventional dairy ice creams and tobe considered to be included in healthy diets.

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2. MATERIAL AND METHODS

2.1. Preparation of ice cream

The main ingredient used for RIC production was rice milk. The protocol for the standardization of rice milk production included the method of partial thermal fermentation.According to this250 g of brown rice were soaked in 500ml of tap water for 14 hours in an incubator at 50^{o}C. Then 1000 ml of tap water was added and mixed and homogenized for 5 min with a hand blender (KENWOOD 800W) to create a smooth consistency. The final amount of the produced rice milk was approximately 1360 ml.
Moreover, four combinations of hydrocolloids were tested as emulsifiers (xanthan gum, guar gum, locust bean gum, sodium alginates, k-carrageenan), with the total concentration to range from 0.15 to 0.45% [2](Table 1). Positive synergistic acts are reported in the literature between locust bean gum (LBG) with k-carrageenan and guar gum, xanthan gum with guar gum and xanthan gum and LBG [14, 15]. Moreover, another two combinations of k-carrageenan with pectin and salep (*Orchis*spp) were also used.

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For the preparation of the final product RIC, glycerin and lemon juice were added to the mixture according to Table 1. Also, a control recipe of conventional industrial-grade ice cream was prepared to carry out proper comparisons. For the production of 100 g of control we followed IOANNOU industrial ice cream protocol: 1) 67g of semi-skimmed milk 3.5%, 2) 10.6 g of milk cream 35%, 3) 2.35 g milk powder 1.5%, 4) 3.77 g of FAMA Food Service (Greece) ice cream powder BASE-50 type, 5) 3.35 g dextrose, and 6) 12.93 g of granulated sugar.

Table 1: Ingredients of four formulations of rice ice cream base using four combinations of hydrocolloids

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	Amount per 100 g formula (g)					
Raw materials	**RIC1**	**RIC2**	**RIC3**	**RIC4**	**RIC5**	**RIC6**
Rice milk	77.00	77.00	77.00	77.00	77.00	77.00
Granulated sugar	21.77	21.77	21.77	21.62	21.50	21.50
Glycerin	0.30	0.30	0.30	0.30	0.30	0.30

Lemon juice	0.60	0.60	0.60	0.60	0.60	0.60
Xanthan gum	0.15	0.15	0.00	0.15	0.00	0.00
Guar gum	0.15	0.00	0.15	0.00	0.00	0.00
Locust bean gum	0.00	0.15	0.15	0.15	0.00	0.00
Sodium alginates	0.00	0.00	0.00	0.15	0.00	0.00
k-carrageenan	0.03	0.03	0.03	0.03	0.30	0.30
Pectin	0.00	0.00	0.00	0.00	0.30	0.00
Salep	0.00	0.00	0.00	0.00	0.00	0.30

In all formulations the ingredients were mixed wellusing a hand blender in a pot, and 20 g of green tea biomass was added as a flavoring agent. Then themixture was heated and pasteurized at 87^{o}C for 30 sec by continuous stirring. The mixture was left to cool down until the temperature of 40°C was reached. Then the mixture was placed in a professional ice cream maker machine (MUSSO Giardino, 450 Watt, Overrun 35%) and left for 30 min to produce the final product. After production, all samples were placed in a freezer at -4^{o}C for maturation and stored until further analysis.

2.2. Meltdown and Overrun

The effect of the different hydrocolloids was evaluated using the method described by Pon et. al., [16]. For the determination of the ice cream meltdown, 100 g of each ice creamsample was placed on a wire mesh attached to a cylinder and maintained in a growth chamber at a constant temperature of 25^{o}C and relative humidity (50%±1%). The dripped volume was measured at 5 min intervals for a total of 45 minutes. The first drop time was measured as the volume drip per minute andthe data recorded was used to determine the "Melting rate" in g per 5 min.Moreover "Overrun" was determined, a parameterthat corresponds to the air that the matrix incorporates during the production of the ice cream, mainly during the freezing of the mixture of ingredients. Overrun was measured by comparing the weight of mix and ice cream in a fixed volume container according to Özdemir et al., [17]. The process was repeated twice for each formulation.

Furthermore, RIC was tested for partial or total granulated sugar substitution, using brown sugar, honey, carob honey and stevia glycosides, in several substitution ratios (Table 2).The tested treatments were: $RIC1_{CO}$= Control (sugar 100%), $RIC1_{CA}$= carob honey 70%, $RIC1_{H}$= honey 30%, $RIC1_{S}$=sugar 70% + stevia 30% and $RIC1_{B}$= brown sugar 100%. The formulation RIC1 was used as the most promising one according to the melting rate and overrun attributes.

Table 2: Substitution of granulates sugar by sweeteners

Sweeteners	Amount of sweetener (%)				
	$RIC1_{CO}$	$RIC1_{CA}$	$RIC1_{H}$	$RIC1_{S}$	$RIC1_{B}$
Granulated sugar	100	0	0	70	0
Carob honey	0	70	0	0	0
Honey	0	0	30	0	0
Stevia	0	0	0	30	0
Brown sugar	0	0	0	0	100

RIC= rice ice cream, $RIC1_{CO}$= Control (sugar 100%), $RIC1_{CA}$= carob honey 70%, $RIC1_{H}$= honey 30%, $RIC1_{S}$=sugar 70% + stevia 30% and $RIC1_{B}$= brown sugar 100%

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2.3. Organoleptic evaluation

For the organoleptic evaluation, 15 semi-trained panelists participated according to the "Quantitative Descriptive Analysis" modified by Lawless, H. T. & Hildegarde, [18].

3. RESULTS AND DISCUSSION

3.1. Hydrocolloids

3.1.1. *Overrun*

The structure of the RIC has been greatly improved by the addition of hydrocolloids to keep the ice cream as smooth and consistent as possible. Overrun values ranged from 10.9 to 40.5% for all the tested formulations (Table 3). Manufacturers report optimum overrun values ranging from 30 to 60% depending on the type of machine, the mix, and the type of produced ice cream (Stoelting, Specialized Equipment LLC, ROKK and Sentry). In the "gravity machines", such as the one we used in our study, ice creams with overrun values between 25%-40%, mean that the final product will be wet, refreshing, and with heavy character [19]. In addition, "pressurized machines" produce ice creams with overrun values ranging between 45% to 60%, meaning that the final products will be fluffy and light.Moreover, low overrun values (19%) in plant-based ice creamswere reported by Pontonio et al., [20]. Additionally, overrun values between 25 and 35% were reported by Elhassan et. al, [21] in ice cream with gums emulsifiers. The overrun value of the control ice cream (dairy) was 40%, which is standard for a conventional hard ice cream. In the case of RIC,overrun values in RIC1, RIC3 and RIC2 ranged from 33 to 32%, which can be characterized within the acceptable range of hard ice cream. Relative overrun values were reported by Jareonnon et l., [22] ranging from 37 to 38% in rice bran oil ice cream recipes, while we should consider that those recipes include fat derivedby rice bran oil. On the contrary, low overrun values appeared in RIC4 and RIC5 showing that these hydrocolloid combinations used in the formulations are not acceptable and suitable for RIC. Thus, the hydrocolloid combinations xanthan gum 0.15%, guar gum 0.15%, k-carrageenan 0.03% (RIC1), xanthan gum 0.15%, LBG 0.15%, k-carrageenan 0.03% (RIC2), guar gum 0.15%, LBG 0.15%, k-carrageenan 0.03% (RIC3), were the most acceptable hydrocolloid combinations.

3.1.2. Meltdown

Furthermore, the melting rate showed a trend for giving lower values for the RIC3 and RC4 (5.77 and 5.95 g/5 min), with no big differences compared to RIC1 and RIC2 (6.93 and 6.81 g/5 min), while the highest values appeared in RIC5 and RIC6 (Table 3). A lower melting rate relates to the sustainability of the ice cream's shape, which is typically evaluated as a good quality ice cream [23]. Therefore, there is a trend that the most acceptableformulations with the most successful hydrocolloid combinations were RIC4 and RIC3. However, there are no reports in the literatureofa standard ideal melting rate in conventional milk ice cream, due to the variety of personal preferences and the types of the ice creams. However, ice creams that melt too quickly are often perceived as being of lower quality as they tend to have a watery texture, while those that melt too slowly may be perceived as being too dense or heavy. The ideal melting rate would be one that balances the desired texture and consistency of the ice cream with a melting rate that allows it to be enjoyed before it becomes too liquid. On the Dream Scoops website several popularin USA ice creams brabds are presented with their overrun values (24). Thus, good ice cream has a melting time of 20-30 minutes per 100 g of material at room temperature [25, 26]. Therefore, according to our results,the RICs did not exceed the limits of acceptable ice creams concerning the meltdown parameter.

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Table 3. Results of the meltdown and overrun with different hydrocolloid combinations

RIC formulations	Melting rate (g / 5 min)	Overrun (%)
RIC1	6.93±3.06	33.96±4.02
RIC2	6.81±2.99	32.74±0.00
RIC3	5.95±3.11	33.62±2.42
RIC4	5.77±2.64	10.91±1.28
RIC5	9.56±5.06	17.35±0.01
RIC6	9.50±5.70	16.87±0.49
Control	11.06±3.38	40.56±5.32

RIC= rice ice cream, *Means ± Standard Deviation*

Overall, combining the overrun and meltdown results, the most acceptable formulations appeared to be RIC1 and RIC2. Moreover, in comparison with thecontrol ice cream, all RIC melting rates were lower. These differences couldbe the results of the presence of animal fat inmilk used to make the control ice cream.

3.2 Sugar substitution

The substitution of sugar appears to alter the overrun and the meltdown of the RIC formulations (Table 4). The highest overrun value appeared in the $RIC1_S$ (40.56%) with a low melting rate of 5.34 g/5 m, showing that sugar substitution with stevia was the most promising one. Compared to the control overrun value was 50% lower, while melting rate was almost the same. Thus, 30% of stevia played an important role and contributed to the improvement of the volume and the sustainability of the ice cream's shape, compared to all the other substitutions. Moreover, the $RIC3_{CA}$ gave a greater overrun value than the control and similar melting rates. On the contrary, the lower overrun value appeared in $RIC3_B$, whilethe melting rate was similar to the other formulations.

Overall, the sugar substationwith stevia resulted in an improvement of the desirable properties of the ice cream.

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Sugar substitutions	Melting rate (g / 5 min)	Overrun (%)
RIC1$_{CO}$	5.99±2.72	39.27±1.31
RIC1$_{CA}$	6.01±2.30	39.03±0.93
RIC1$_{H}$	6.05±2.70	36.64±0.19
RIC1$_{S}$	5.34±2.83	56.69±2.68
RIC1$_{B}$	6.02±2.95	27.78±0.86

Table 4. Results of the meltdown and overrun with different combinations of sugar substitutes in RIC1

RIC= rice ice cream, *Means ± Standard Deviation*

3.3. Organoleptic evaluation

The analysis of the organoleptic evaluation revealed differences between the formulations after sugar substitution in the most acceptable formulation RIC1 (Table 5). The panelists evaluated RIC1$_{H}$with the highest ranking in sweetness (4.17) followed by RIC1$_{B}$ (3.92), while the lowest value appeared in the control (RIC1$_{CO}$). Similarly, RIC1$_{H}$ was ranked as the best in gumminess among (3.58) the five formulations followed by RIC1$_{CA}$ (3.42) and RIC1$_{S}$ (3.25), however, these evaluations were very close. The best formulation in the ice crystals evaluation appeared to be the control RIC1$_{CO}$ (2.38) followed by RIC1$_{S}$ (2.83). Finally, total acceptance evaluation appeared to be the highestfor RIC1$_{S}$ (4.08) followed by the control RIC1$_{CO}$, but with no big differences between them, while RIC1$_{CA}$ was the least acceptable formulation.

Overall, afterorganoleptic evaluation, it was evitable that panelists rated RIC1S as the most acceptable according to the four evaluated parameters.

Table 5: Organoleptic evaluation of the RIC1 formulations after sugar substitution

Sugar substitution	Sweetness	Gumminess	Ice crystals	Total Acceptance
RIC1$_{CO}$	3.38±0.87	2.54±0.78	2.38±1.19	3.91±1.19
RIC1$_{CA}$	3.58±0.87	3.42±0.87	3.08±0.76	3.50±1.45
RIC1$_{H}$	4.17±0.95	3.58±0.78	3.33±1.01	3.75±1.34
RIC1$_{S}$	3.67±0.48	3.25±0.95	2.83±0.73	4.08±0.95
RIC1$_{B}$	3.92±0.80	3.08±1.12	3.42±0.95	3.67±0.93

Means ± Standard Deviation

4. CONCLUSION

A novel vegan ice cream formulation was developed, analyzed, and evaluated.Thus, there is an evident trend that the formulation with the combination of xanthan gum 0.15%, guar gum 0.15%, k-carrageenan 0.03% (RIC1) was the most acceptable in terms of emulsification, as it gave the highest rankings in the ice cream consistency. Furthermore, the most acceptable sugar substitution was the formulation with stevia. Overall, rice milk-based ice creams can be a promising substitution of dairy milk for consumption by people with lactose intolerance and vegan groups. Therefore, it is evidentthat the ice cream industry can follow a quite straightforward workflow to investin the production of rice milk ice creams, which can cover the needs of people belongingto special dietary groups. Moreover, the formulations presented in the current study, with some modifications, in the emulsifiers phase, could be prepared at the households to serv the people with needs of special diets.

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COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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