applied sciences

MDPI

Article

Plant-Based Milks: Alternatives to the Manufacture and Characterization of Ice Cream

Ana Leahu *, Sorina Ropciuc and Cristina Ghinea

Faculty of Food Engineering, Stefan cel Mare University of Suceava, 720229 Suceava, Romania; sorina.ropciuc@fia.usv.ro (S.R.); cristina.ghinea@fia.usv.ro (C.G.)
* Correspondence: analeahu@fia.usv.ro

Abstract: This study investigated the potential use of dietary fibers (psyllium and pectin fibers added in different proportions of 0–10%) to improve the rheological, textural, and sensory characteristics of vegetable ice cream using vegetable milk (almond and hemp milk). Hemp milk was obtained from the peeled seeds of the industrial hemp plant, which includes varieties of *Cannabis sativa*, which have a low content of the psychotropic substance tetrahydrocannabinol (THC) and are grown for food. The rheological characteristics of the mix and ice cream were determined by using the Haake Mars rheometer. Compared with the control sample, the viscosities of the mix in all samples analyzed were enhanced with the addition of dietary fibers, due to the occurrence of interactions and stabilizations. The viscoelastic modules G′ G″ were determined on ice cream samples at a temperature of −10 °C. The elastic and viscous modulus showed high values with the increase of the addition of 6% dietary fibers. The textural characteristics were assessed by the shear strength of a layer of ice cream at a temperature of −4 °C. Hardness, firmness, and adhesiveness were influenced by the size of their ice crystals, the fat content, and the percentage of dietary fibers added. The sensory analysis of the ice cream showed higher overall scores for the almond milk ice cream, because the sweet taste was appreciated with a maximum score, while the hemp milk ice cream was evaluated for flavor and taste.

Keywords: vegetable ice cream; dietary fibers; sensorial properties; rheological properties

check for updates

Citation: Leahu, A.; Ropciuc, S.; Ghinea, C. Plant-Based Milks: Alternatives to the Manufacture and Characterization of Ice Cream. *Appl. Sci.* **2022**, *12*, 1754. https://doi.org/10.3390/app12031754

Academic Editor: Alessandra Durazzo

Received: 19 January 2022
Accepted: 5 February 2022
Published: 8 February 2022

1. Introduction

In recent times, there has been a trend towards the development of innovative, readily available, reasonably priced, yet safe foods that offer consumers benefits such as improved health or the prevention of health complications associated with diet beyond basic nutritional functions [1]. It has been found that changes in the eating habits of health-conscious consumers, strongly influenced by the increasing incidence of lifestyle diseases, such as heart disorders and depression, have given rise to new functional foods and products on the market [2]. Ice cream is a very popular and delicious frozen dessert, made from dairy products such as milk, cream, and natural or artificial sweeteners, while in recent years, plant-based milk substitutes have begun to be used [3]. In this sense, dietary ice cream is a new product on the Romanian market and is increasingly preferred, due to a different taste, along with being enriched with various delicious flavors. This dietary ice cream is chosen especially by vegetarians, raw vegans, people with lactose intolerance or those who generally prefer a healthy lifestyle. According to Eurostat [4], ice cream consumption in Romania is the lowest in Europe, respectively 1.6 kg/capita, and ice cream is considered to be a refreshing product, in the hot season as a dessert. Ice cream is a. physico-chemical complex characterized by hardness and melting properties, usually contains at least 10% fat, stabilizers, and sweeteners. The use of plant-based milk substitutes from soy (*Glycine* max), cashew (*Anacardium occidentale*), hazelnut (*Corylus*), coconut (*Cocos nucifera*), hemp (*Cannabis sativa*), or almonds (*Prunus dulcis*) and dietary fiber allow for final products with the texture, hardness, and firmness characteristics of milk ice cream [5]. Plant-based milk is free of cholesterol and has unsaturated fats, vitamins, minerals, and antioxidants, which is why they are considered functional foods and nutraceuticals [6].

Almonds (*Prunus dulcis* Mill. DA Webb) have a high content of fatty acids, lipids, amino acids, proteins, carbohydrates (including dietary fiber), vitamins, and minerals which contribute to improving artery health, reducing high blood pressure, has positive effects in improving diabetes and metabolic syndrome [7]. In recent years, almond milk beverage is promoted as a healthy alternative to cow's milk have potential prebiotic properties due to the presence of bioactive compounds such as vitamins, especially vitamin E which cannot be synthesized by the body, flavonoids, and polyphenols [8,9].

In addition, consumers choose plant-based milk alternatives instead of milk due to its numerous positive health effects on the human body, a desire for a healthy lifestyle, and environmental awareness. The solution to this problem may be to drink almond drink instead of cow's milk, as it contains a vitamin E content of 6.33 mg 100 g^{-1}, which represents 42% of the recommended daily allowance of 15 mg [6,10].

The non-drug variety *Cannabis sativa* subsp. *sativa*, hemp (*Cannabis sativa* L.) seeds contain approx. 20–25% protein with a biological value similar to chicken egg white, as well as considerable amounts of vitamins, minerals (magnesium, copper, phosphorus, and calcium) and dietary fiber. Hemp milk has a high nutritional value with a low content of saturated fats, a good percentage of polyunsaturated fatty acids (PUFA) ω-3 and ω-6, and low allergenicity [9]

According to Szparaga et al. [11], hemp-based milk substitutes provide very low amounts of protein (3.23 g/100 g) and lipids (21.08 g/100 g) and can be an alternative to consumers who seek gluten-free food. The use of hemp seed milk has not yet been widely tested in food production. Hemp milk is unstable with a tendency to flocculate, being an oil-in-water emulsion, which is a challenge in the industry, as it leads to loss of quality and validity. The use of stabilizing substances can increase the cost of production [12]. Hemp seed milk can be a very valuable new ingredient for the food industry due to its potential as natural emulsions of polyunsaturated fatty acids (PUFAs), essential fatty acids (EFAs), and other fat-soluble bioactive compounds.

Dietary fibers include resistant starch and non-starch polysaccharides, oligosaccharides, and various lignified compounds that are not digested by enzymes of the gastrointestinal tract, but also have functional properties in food, for example, increase water retention, or contribute to emulsification or gel formation. Moreover, the addition of dietary fiber to foods can help change texture, avoid syneresis and increase the shelf life of foods [1]. Dietary fiber is prebiotic, improving the activity of beneficial intestinal bacteria, so they can prevent many gastrointestinal disorders [13]. Additionally, dietary fiber plays an important role in the treatment of diabetes, decreases the risk of coronary heart diseases, reduces the risk of cancer in the colon or rectum, and relieves symptoms caused by lactose intolerance [2]. A recent meta-analysis by McRorie et al. [14] showed that highly viscous soluble fiber (β-glucan, psyllium, and crude guar gum) can effectively reduce high serum cholesterol levels and improve glycemic control. Whole grains (especially the pericarp), vegetables, fruits, and nuts are one of the most important sources of dietary fiber [6]. Resistant starch present in food is considered dietary fiber that is non-digestible by enzymes in the small intestine of healthy people. Therefore, to produce vegetable milk ice cream with the desired textural properties and sensory attributes, it can be used a mixture of plant-based milk on almond and hemp and dietary fiber.

In recent decades, there have been significant changes in food patterns and food consumption. In association with this, there has been a growing demand for plant-based milk alternatives due to milk allergy, lactose intolerance but which can provide health benefits. Moreover, in the presented study, agave syrup was used as an ingredient to prepare a vegan ice-cream mix. Agave syrup (natural sweetener) is a product with functional properties, and the intake has beneficial properties for human health, such as high prebiotic capacity and a low glycemic index score.

The aim of this study was to investigate the impact of different concentrations (0–10%) of psyllium and pectin fibers of vegetable ice cream, which is comparable to ordinary ice cream in terms of rheological, textural, and sensorial parameters.

2. Materials and Methods

2.1. Materials

Almond seeds (Pronat SRL Romania), agave syrup, and vanilla were all purchased from the local market. High quality peeled hemp (Pronat SRL Romania) was purchased from local pharmacies. Other ingredients were psyllium and pectin fiber were purchased from Enzymes & Derivates SA Neamt, Romania.

2.2. Methods

2.2.1. Almond Milk Preparation

The almond milk was prepared according to the method previously described. The almond seeds (300 g) were soaked overnight at 4 °C in 900 mL of distilled water. For milk extraction, the almonds were mixed with distilled water (1:10 *g/v* ratio), ground in a blender and filtered. The almond milk obtained was stored for further analysis at 4 °C [15].

2.2.2. Hemp Milk Preparation

Hemp milk was freshly prepared in the laboratory. The dehulled seeds of hemp (300 g) were soaked for 10 h at 20 °C in 900 mL of distilled water. For milk extraction, the hemp seeds were mixed with distilled water (1:10 *g/v* ratio), ground in a Tefal laboratory easy soup (France) and filtered [11].

2.2.3. Ice Cream Preparation

In order to obtain the ice cream, the mixtures were prepared using the formula as shown in Table 1. The milk was heated to 80 °C, then homogenized and frozen in a 1.5-L ice cream maker. The steps followed for the ice cream manufacturing are illustrated in Figure 1, as described before by Leahu [16]. The ice cream was made in Ice Cream Maker Machines (Cuisinart.com). Finally, the samples were frozen and stored in a refrigerator at −22 °C for subsequent analysis. The ice cream production process referred to the description in previous studies [17–19].

Table 1. The content of components used in ice cream mix formulation.

Samples	% Dietary Fiber	Volume of Milk (mL)	% Almonds/Hemp Flour	% Agave Syrup	Vanilin %
A_Psy	0	100	3	5	1
A1_Psy	2	100	3	5	1
A2_Psy	4	100	3	5	1
A3_Psy	6	100	3	5	1
A4_Psy	8	100	3	5	1
A5_Psy	10	100	3	5	1
H_Pec	0	100	3	5	1
H1_Pec	2	100	3	5	1
H2_Pec	4	100	3	5	1
H3_Pec	6	100	3	5	1
H4_Pec	8	100	3	5	1
H5_Pec	10	100	3	5	1

A_Psy—ice cream with almond milk with 0% psyllium; A1_Psy—ice cream with almond milk with 2% psyllium; A2_Psy—ice cream with almond milk with 4% psyllium; A3_Psy—ice cream with almond milk with 6% psyllium; A4_Psy—ice cream with almond milk with 8% psyllium; A5_Psy—ice cream with almond milk with 10% psyllium; H_Pec—ice cream with hemp milk with 0% pectin; H1_Pec—ice cream with hemp milk if 2% pectin; H2_Pec—ice cream with hemp milk if 4% pectin; H3_Pec—ice cream with hemp milk if 6% pectin, H4_Pec—ice cream with hemp milk if 8% pectin; and H5_Pec—ice cream with hemp milk if 10% pectin.

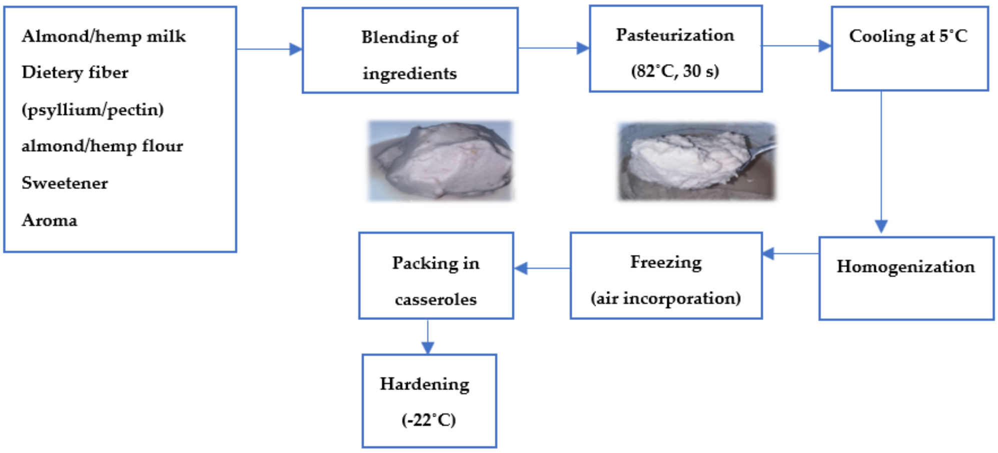

Figure 1. Manufacturing process of ice cream.

2.2.4. Ice Cream Analysis

Physico-Chemical Analyses of Ice Cream Mix

The titratable acidity was determined according to the AOAC 920.124 method [20]. The pH values were measured according to the AOAC 14.022 method using a digital pH meter HACH HQ 30d flexi [21]. The soluble solids percentage was determined by using an Abbé refractometer. Two drops of the ice cream mix were placed on the prism of the refractometer. The soluble solids content was read directly on the refractometer scale [21]. The fat content was determined by applying the chemical method of using an ice cream butyrometer (according to Roeder's weighing method). The protein content was determined by using the Kjeldahl chemical method [22].

Rheological Analysis of Ice Cream Mix

The dynamic rheometer, model Haake Mars 40, was used for determination of ice cream mix rheological characteristic, after cooling at 5 °C. Viscosity and vascoelastic modulus of the ice cream mix were determined over time, by using the plate/plate system with a diameter of 80 mm for the plate and 40 mm for the rotor. The temperature during the analysis remained constant. Vascoelastic modules were obtained by recording the frequency from 10^{-1} to 10 Hz at a temperature of 5 °C. Numerical values for viscosity and modulus G prime G s. were obtained by using Microsoft Excel [23].

Textural Analysis

A 50-g sample of ice cream was used to determine the texture. Ice cream tubs were taken out of the freezer and left at room temperature for two minutes. The ice cream samples were analyzed texturally by using the Perten Texturometer with 45° cone probe (P-CO45S), a trigger force of 4 g, a compression percentage of 30%, and a test speed of 2 mm/s. The hardness and adhesiveness of the ice cream samples were determined.

Sensory Analysis

The 12 ice cream samples were proposed for sensory analysis to a group of 30 members selected from the students of the Faculty of Food Engineering. The coded samples were offered to the tasters and the sensory evaluation was performed by using the preference test. The preference or ranking test was carried out according to the ISO 8587:2006 standard.

It used a 9-point hedonic scale (from 1 = "Dislike Extremely" to 9 = "Like Extremely", with 5 = "Neither Like nor Dislike"). The investigated attributes included flavor, taste, appearance, consistency, and overall acceptability [24].

Statistical Analysis

The experiments were assayed in triplicates (n = 3) and the results were expressed as mean ± S.E.M (standard mean error) values. For the comparison among the different formulations of the average values of all the compositional and physical–chemical properties, an analysis of variance (ANOVA) with a confidence interval of 95% ($p < 0.05$) using the Tukey test was carried out. The statistical analysis was carried out using XLSTAT statistical software, version 2021. The correlations between the quantitative variables and the qualitative (sensory characteristics) variables were interpreted by analyzing the main components using the Matlab 2021b program.

3. Results and Discussion

Given the importance of adding fiber in improving the quality characteristics of ice cream, in this research the viscosity, hardness, firmness, adhesiveness, physicochemical, and sensorial properties of the ice cream formulations were studied. Five formulations were prepared with almond milk and psyllium fiber, while the other five were prepared with hemp milk and pectin.

3.1. Physicochemical Analyses of Cream Mix

In Table 2, the results obtained after physicochemical analysis of ice cream samples are presented. The titratable acidity is maintained in the range of 0.17–0.20 g/100 g lactic acid for all samples of the almond cream mixture (including those with the addition of psyllium fiber). Hemp milk with added pectin has higher titratable acidity values as the percentage of added pectin increases. Compared to the control sample (H0_Pec) which shows the value of 0.26 g/100 g lactic acid, the addition of 10% pectin leads to an increase in acidity to the value of 0.80 g/100 g lactic acid. From Table 2, it can be observed that the pH of almond milk ice cream and addition of psyllium fibers samples did not vary, while the pH of hemp milk ice cream samples with pectin decreased with the addition of a higher concentrations of pectin [25].

Table 2. Values of the physicochemical parameters.

Sample	Physicochemical Parameters				
	Titratable Acidity, g Lactic Acid/100 g of Total Solids	**pH**	**Soluble Solids, °Brix**	**Fat, %**	**Protein, %**
A0_Psy	0.16 ± 0.02 ^{h}	6.2 ± 0.02 ^{a}	23.12 ± 0.01 ^{b}	2.67 ± 0.03 ^{c}	1.09 ± 0.03 ^{f}
A1_Psy	0.17 ± 0.01 ^{g}	6.1 ± 0.01 ^{a}	23.26 ± 0.02 ^{a}	2.58 ± 0.03 ^{d}	1.12 ± 0.03 ^{f}
A2_Psy	0.17 ± 0.01 ^{g}	6.1 ± 0.02 ^{a}	23.46 ± 0.01 ^{a}	2.5 ± 0.04 ^{e}	1.32 ± 0.02 ^{e}
A3_Psy	0.17 ± 0.01 ^{g}	6.1 ± 0.01 ^{a}	23.16 ± 0.01 ^{b}	2.57 ± 0.04 ^{d}	1.46 ± 0.03 ^{e}
A4_Psy	0.17 ± 0.01 ^{g}	6.1 ± 0.03 ^{a}	23.13 ± 0.03 ^{b}	2.61 ± 0.02 ^{c}	1.68 ± 0.03 ^{d}
A5_Psy	0.17 ± 0.02 ^{g}	6.1 ± 0.02 ^{a}	23.13 ± 0.04 ^{b}	2.53 ± 0.01 ^{e}	1.75 ± 0.02 ^{d}
H0_Pec	0.26 ± 0.03 ^{f}	5.3 ± 0.02 ^{b}	21.25 ± 0.03 ^{d}	3.24 ± 0.01 ^{b}	2.04 ± 0.02 ^{c}
H1_Pec	0.28 ± 0.02 ^{e}	5.1 ± 0.03 ^{b}	21.39 ± 0.04 ^{d}	3.20 ± 0.02 ^{b}	2.32 ± 0.02 ^{c}
H2_Pec	0.34 ± 0.01 ^{d}	4.9 ± 0.02 ^{c}	21.54 ± 0.04 ^{c}	3.41 ± 0.04 ^{a}	2.57 ± 0.01 ^{b}
H3_Pec	0.48 ± 0.02 ^{c}	4.7 ± 0.01 ^{c}	21.56 ± 0.03 ^{c}	3.5 ± 0.04 ^{a}	2.61 ± 0.02 ^{b}
H4_Pec	0.63 ± 0.04 ^{b}	4.2 ± 0.01 ^{d}	21.33 ± 0.03 ^{d}	3.5 ± 0.04 ^{a}	2.79 ± 0.01 ^{a}
H5_Pec	0.80 ± 0.03 ^{a}	3.8 ± 0.01 ^{e}	21.47 ± 0.03 ^{c}	3.24 ± 0.03 ^{b}	2.66 ± 0.03 ^{b}

$^{a–h}$ Mean values in the same column (corresponding to the same letter) indicate statistically differ significantly ($p < 0.05$).

The pH values of the almond milk cream mix samples are around 6, while pH values of the hemp cream mix samples are in the range of 5.3 for the sample without the addition of pectin and 3.8 for the sample with 10% pectin (Table 2).

The refractometric soluble solids (Table 2) showed values between 23.12–23.46 °Brix to the mixture of almond milk ice cream and addition of psyllium fibers for the control sample and the sample with 4% psyllium. Hemp milk samples had soluble solids values in the range of 21.25 °Brix in the control sample and 21.56 °Brix in the sample with the addition of 6% pectin.

The fat content (Table 2) determined for the almond milk ice cream mix was 2.5–2.6%, being correlated with the fat of the almond milk. Hemp milk samples had a fat content relative to milk fat, which was around 3.5%.

The results obtained for the protein content (Table 2) indicate values of 1.09% in the control sample with almond milk and a maximum of 1.75% in the sample with the addition of 10% psyllium fiber. Hemp milk ice cream mix had higher values for protein content due to the fact that hemp milk has a higher protein content, the control sample with hemp milk had a content of 2.04% and the sample with 8% pectin fibers had a higher protein content, 2.79%. According to Kozłowicz et al. [26] the protein content in the ice cream supplemented with Moldavian dragonhead bagasse (MDB) changed significantly ($p < 0.05$) from 10.16 g per 100 g (w/w) for the 1% MDB sample to 12.07 g per 100 g (w/w) for ice cream with 3% MDB addition.

The analysis of the correspondences between the quantitative variables obtained after physico-chemical parameters determination is represented in Figure 2. The analysis of the correspondence places the results at a very short distance between them. This arrangement indicates a strong association between the chemical characteristics of pH and titratable acidity—they practically overlap. The variables that express protein and fat are distanced from the values obtained for pH and titratable acidity. No statistically significant changes in the pH and titratable acidity of plant-based milks ice cream were observed regardless of the milk used. The pH value correlated with the titratable acidity of the product and is not influenced by the protein content, but such properties can directly affect the quality and ultimately the acceptability of the product by the consumer. The fat content of the ice cream does not correlate with the pH value. Also, it was desired to develop a recipe based on maintaining a constant content total solids and sugar.

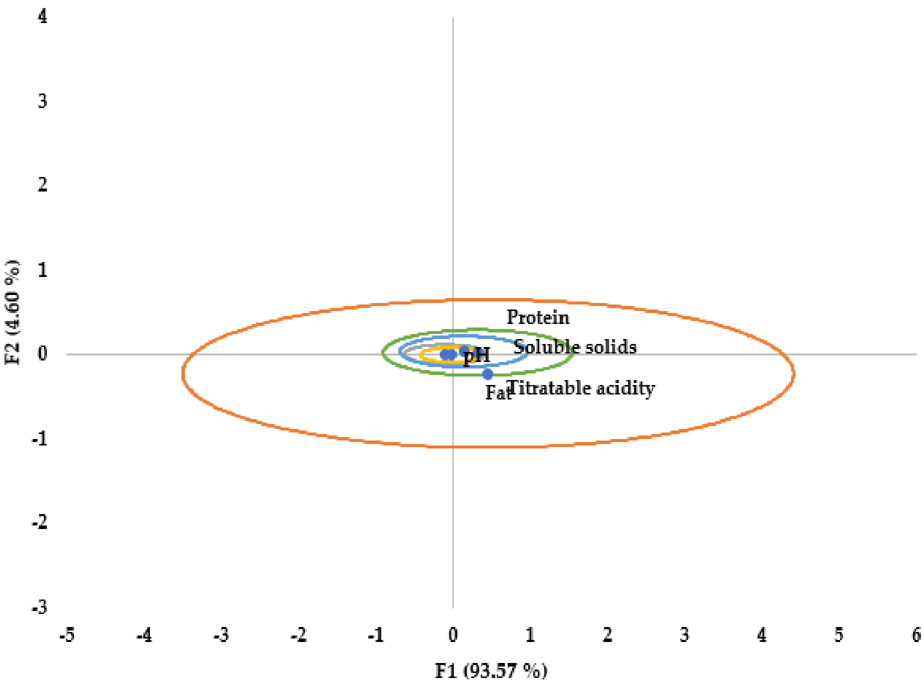

Figure 2. Correspondence analysis between quantitative variables.

3.2. Rheological Analysis of Ice Cream Mix

The average values of the rheological characteristics of the apparent viscosity and the viscoelastic modules made with different milk and with additions of psyllium/pectin are presented in Figures 3–8.

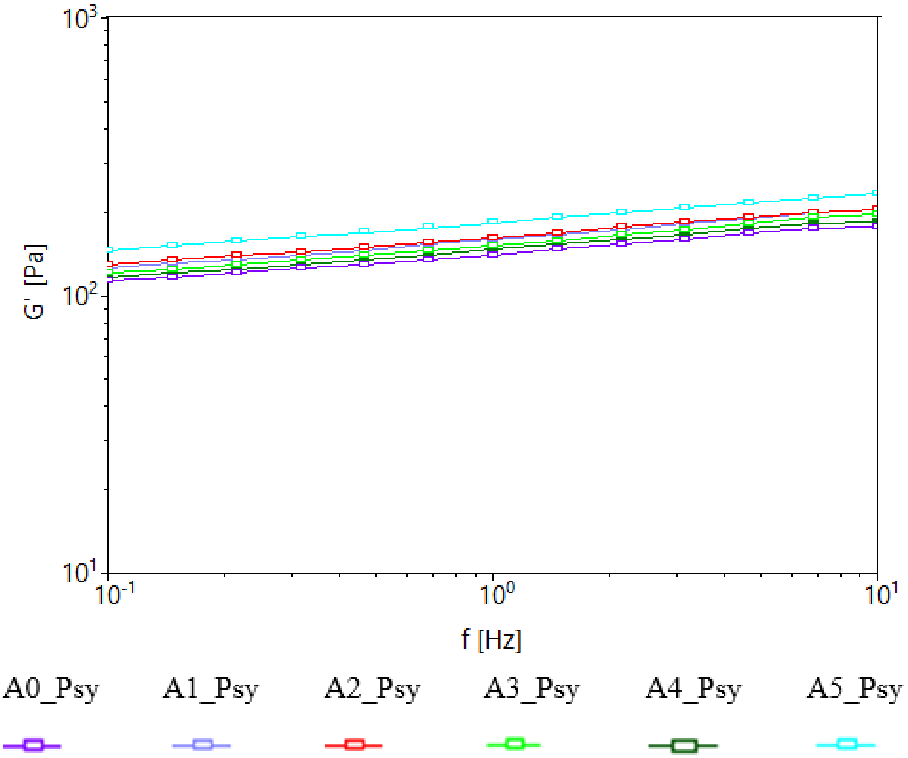

Figure 3. The elastic modulus curves to the ice cream mix with almond milk and psyllium.

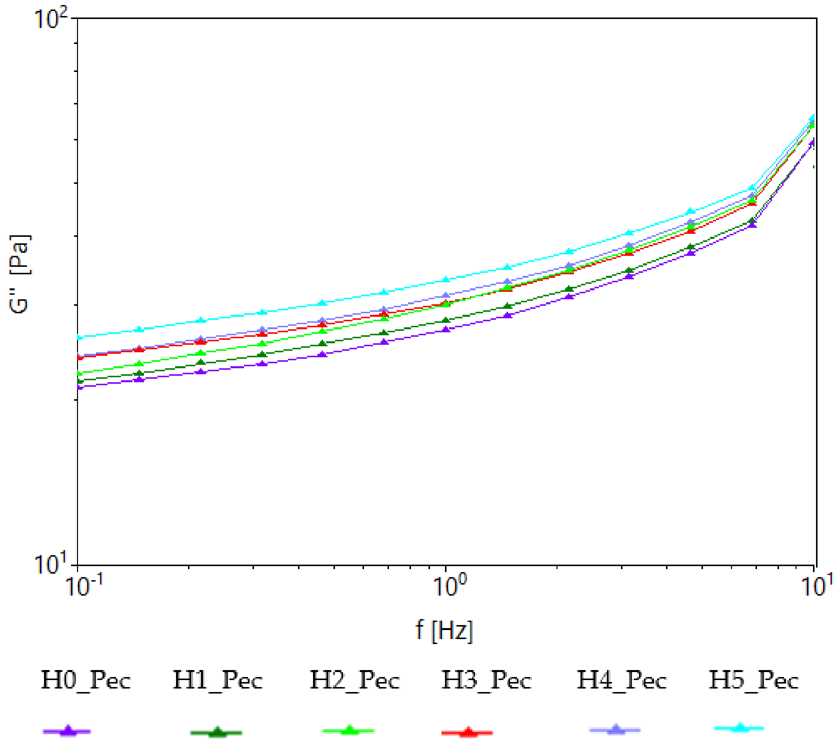

Figure 4. The viscous modulus curves to the mix of ice cream with almond milk and psyllium.

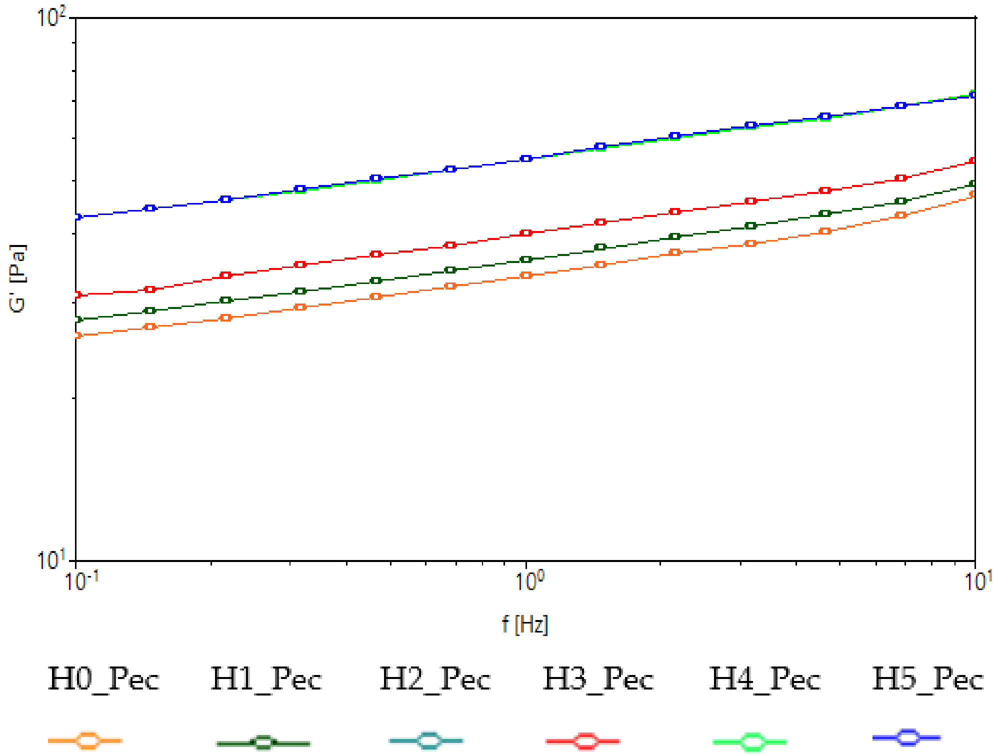

Figure 5. The elastic modulus curves to the ice cream mix with hemp milk and pectin.

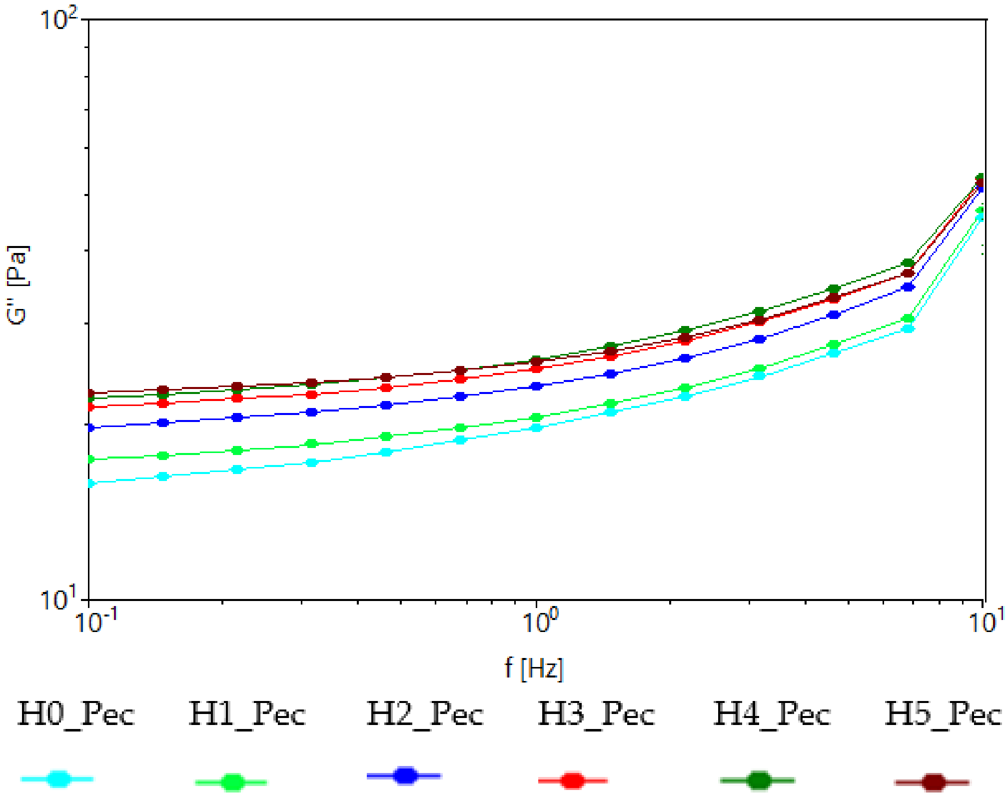

Figure 6. The viscous modulus curves to the mix of ice cream with hemp milk and pectin.

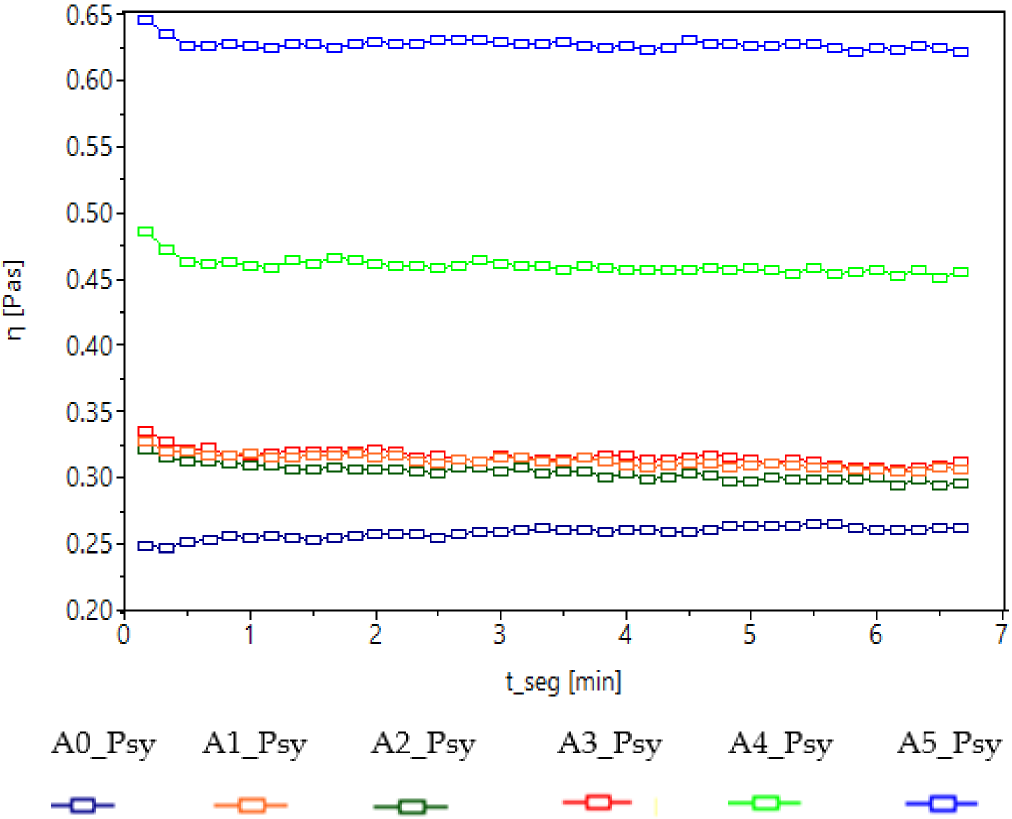

Figure 7. Viscosity curves for the ice cream mix with almond milk the addition of psyllium.

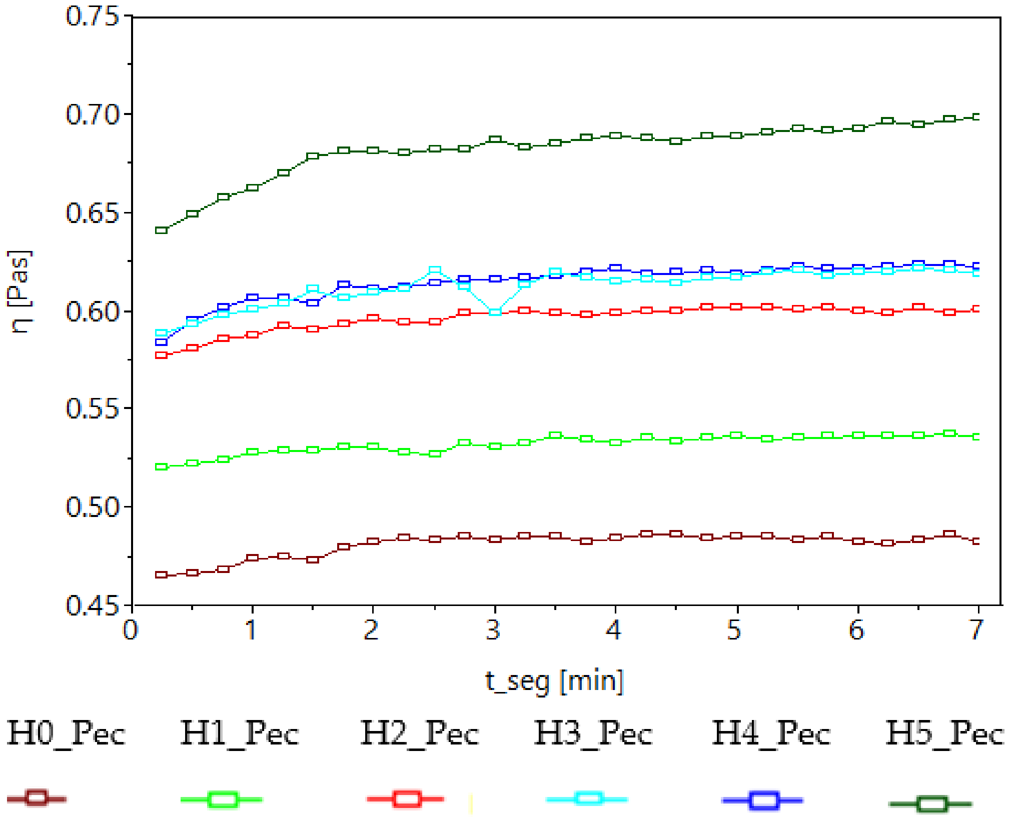

Figure 8. Viscosity curves for the ice cream mix with hemp milk the addition of pectin.

The curves that express the results of the rheological behavior of the ice cream mix with vegetable milk (Figures 3–6) demonstrate that the addition of psyllium and pectin fibers leads to a significant increase in the viscous and elastic mode [27]. The rheological properties of the almond (Figure 3) ice cream mixes showed that an increase in viscoelastic parameters (G′) when the psyllium fiber concentrations increased comparatively with hemp ice cream with pectin fiber (Figure 4). Viscosity curves have the same tendency to increase as the percentage of psyllium added to the mix increases (Figure 5). By comparison, the elastic modulus of pectin-added ice cream mixes increases significantly at 8–10% pectin added (Figure 5).

The viscous modulus of the ice cream mix with hemp milk and pectin fiber shows the same tendency to increase the viscosity with the percentage of pectin (Figure 6). The increase in the viscosity and elasticity of the mix influences the foaming capacity of the mix, the retention of air in the structure of the ice cream and the stability of the emulsion will have a positive effect on the melting resistance of the ice cream [27,28]. The idea that psyllium and pectin fibers form a stable gel structure with high viscosity and pseudoplastic flow behavior can be supported. According to the results obtained by Soukoulis et al. [1] and Valera et al. [25], all samples showed high elastic and viscous behavior in the mixtures obtained with vegetable milk and fiber additives with the role of hydrocolloids [1,25]. The viscosity curves shown in Figures 7 and 8 describe the increase in the viscosity of the ice cream mix as the amount of psyllium and pectin fibers increases. Compared to the control samples (A0_Psy and H0_Pec), the mix has a high viscosity due to the addition of psyllium fiber and pectin, thus increasing the flow resistance and the thickening effect gives the mix stability to the shear action. The higher thickening effect is observed with the addition of psyllium fiber compared to pectin fiber (Figure 7).

The Pearson correlations that are established between the chemical properties of the mixture obtained with almond milk or hemp milk are presented in Table 3. The correlation coefficient between viscosity and fat (r = 0.710), respectively protein (r = 0.753) indicates that the presence of proteins and fat in vegetable milk helps the stability of the mix and the formation of gel binding mechanisms.

These results are justifiable according to Makinen et al. [28]; Elsamani et al. [29] Shinyoung et al. [30]; Adapa et al. [31] which demonstrated that a high protein and fat content of the ice cream mixture with vegetable milk led to an increase in viscosity and a good elasticity of the ice cream mix.

Table 3. Correlation matrix (Pearson (*n*)) between chemical variables and rheological variables.

Variables	G″ Pa	G′ Pa	Viscosity	Titratable Acidity	pH	Soluble Solids	Fat	Protein
G″ Pa	**1**	**0.990**	0.001	0.346	−0.365	−0.409	0.446	0.238
G′ Pa	**0.990**	**1**	0.079	0.455	−0.460	−0.487	0.517	0.341
viscosity	0.001	0.079	**1**	0.453	**−0.697**	**−0.748**	**0.710**	**0.792**
Titratable acidity	0.346	0.455	0.453	**1**	**−0.871**	**−0.722**	**0.753**	**0.845**
pH	−0.365	−0.460	**−0.697**	**−0.871**	**1**	**0.942**	**−0.970**	**−0.964**
Soluble solids	−0.409	−0.487	**−0.748**	**−0.722**	**0.942**	**1**	**−0.960**	**−0.904**
Fat	0.446	0.517	**0.710**	**0.753**	**−0.970**	**−0.960**	**1**	**0.924**
Protein	0.238	0.341	**0.792**	**0.845**	**−0.964**	**−0.904**	**0.924**	**1**

3.3. Textural Properties

The hardness and adhesiveness of the vegetable milk ice cream are represented in Figures 9 and 10. It can be stated that the hardness value increases with the addition of psyllium and pectin fibers. Hemp milk ice cream samples have a higher fat content which leads to a lower increase in hardness compared to almond milk ice cream samples. Changing the type and amount of protein and fat in vegetable milk for the preparation of various ice cream samples have a significant effect on the textural properties of ice cream, which influences the formation of ice cream crystals and increases the hardness and consistency of ice cream. The error limits in Figures 9 and 10 represents the standard deviations.

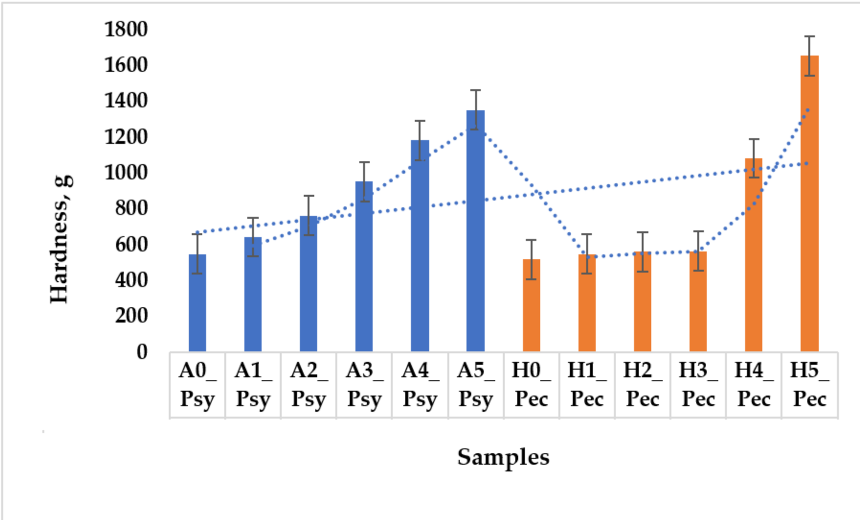

Figure 9. Graphical representation of the results describing the hardness of the ice cream samples.

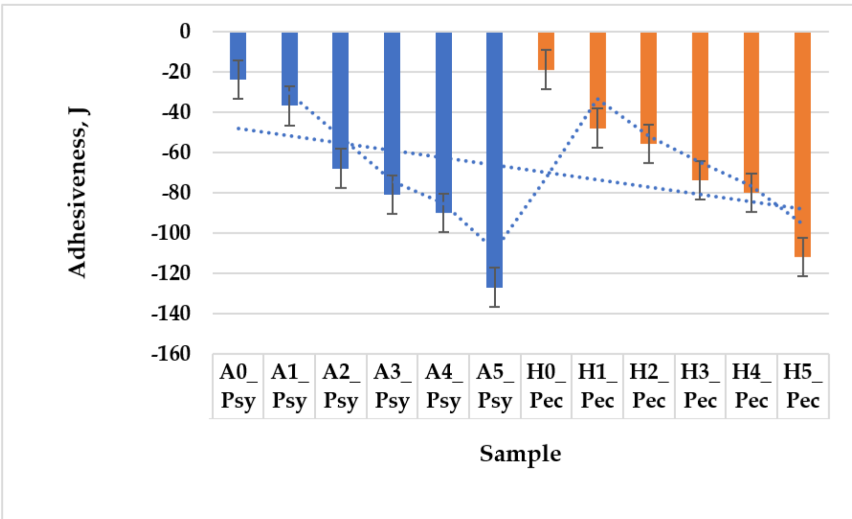

Figure 10. Graphical representation of the results describing the adhesiveness of the ice cream samples.

3.4. Sensory Properties Results

Descriptive sensory panelists evaluated the almond milk and psyllium fiber ice cream samples and also the ice cream samples with hemp milk and pectin fiber. In general, they gave higher overall scores for the almond milk ice cream because the sweet taste was appreciated with maximum score and the hemp milk ice cream was rated for flavor and taste (Table 4). Compared to almond milk ice cream, hemp milk ice cream was characterized by specific sensory properties: high-intensity, slightly unpleasant aromas that were considered to be specific to hemp milk. The consistency and appearance of ice cream with hemp milk and pectin was appreciated as dense, smooth, without ice needles, which allows for the development of taste and consumption in ice cream. Samples of almond milk and psyllium fiber ice cream were less appreciated by sensory experts due to their high consistency and adhesiveness. The panelists reported that the aroma scores of the hemp milk ice cream samples with 8% and 10% pectin fibers were much improved compared to the control samples, while those formulated with 2% and 4% were evaluated with a lower score. The panelists criticized these samples for having a strong hemp aroma. The research conducted in this study may be useful to vegetable ice cream producers [32–34]. This study is the first to define the sensory characteristics of vegetable ice cream with almond milk and hemp with the addition of psyllium fiber and pectin. The descriptive attributes developed can be used for the development of new varieties of vegetable milk ice cream [18,19,35].

Table 4. Average sensory acceptance results on a 9-point hedonic scale.

Formulation	Attributes of Sensory Acceptance				
	Flavor	Taste	Appearance	Consistency	Overall Acceptability
A0_Psy	6.1 ± 0.17 d	6.0 ± 0.23 d	7.2 ± 0.02 b	5.2 ± 0.34 f	6.3 ± 0.02 d
A1_Psy	6.5 ± 0.08 b	6.3 ± 0.18 c	7.3 ± 0.26 b	6.1 ± 0.44 e	6.9 ± 0.03 c
A2_Psy	6.3 ± 0.62 c	6.3 ± 0.12 c	7.2 ± 0.02 b	7.3 ± 0.18 d	7.0 ± 0.03 c
A3_Psy	6.3 ± 0.24 c	6.4 ± 0.40 c	7.2 ± 0.03 b	8.0 ± 0.28 c	8.0 ± 0.01 b
A4_Psy	6.5 ± 0.31 b	6.4 ± 0.35 c	7.4 ± 0.04 b	8.7 ± 0.22 b	8.0 ± 0.02 b
A5_Psy	6.7 ± 0.12 b	6.8 ± 0.27 b	7.8 ± 0.04 a	9.0 ± 0.23 a	8.2 ± 0.01 b
H0_Pec	5.3 ± 0.22 e	6.2 ± 0.22 d	5.4 ± 0.07 e	6.1 ± 0.20 e	5.3 ± 0.02 e
H1_Pec	5.9 ± 0.31 d	5.6 ± 0.31 e	5.6 ± 0.08 e	6.5 ± 0.16 d	6.2 ± 0.01 d
H2_Pec	5.6 ± 0.09 e	6.0 ± 0.42 d	5.8 ± 0.00 d	6.9 ± 0.17 d	6.7 ± 0.03 c
H3_Pec	6.0 ± 0.27 d	6.4 ± 0.12 c	6.2 ± 0.00 d	8.4 ± 0.21 c	6.9 ± 0.01 c
H4_Pec	6.2 ± 0.36 c	7.0 ± 0.24 b	6.8 ± 0.04 c	8.7 ± 0.17 b	7.0 ± 0.00 c
H5_Pec	7.2 ± 0.14 a	7.8 ± 0.16 a	7.9 ± 0.06 a	9.0 ± 0.00 a	8.8 ± 0.01 a

Means that do not share a letter ([a–f]) are significantly different ($p \leq 0.05$).

The analysis of the main components (PCA) was applied to the average values of the textural and rheological attributes to express the correlation ratio between them. The PCA plot (Figure 11) explains the variability of the results obtained by chemical, rheological, textural, and sensory analyses. Axis F1, indicates the positive correlation for almond milk ice cream and on axis F2 are grouped the ice cream samples according to the attributes that characterize them. There is a significant positive association between the control formulations (H0, H1, H2, and H3 in the samples obtained from hemp milk and differentiates in samples H4 and H5 to which pectin was added in proportion of 8 and 10%. For this grouping of samples H4 and H5, it is also noticeable in the sensory analysis; these being appreciated with a high score. The separation between the two F2 axis groups is well differentiated because the results obtained in the determination of chemical, rheological, textural, and sensory characteristics separated the two samples (H5_Pec and H6_Pec) from the rest of the group. The ice cream samples that were formulated with almond milk and psyllium fiber are grouped on the F1 axis according to the positive characteristics. The control sample A0_Psy is significantly different from the rest of the samples, we can express a negative correlation between the control sample and the other almond milk samples.

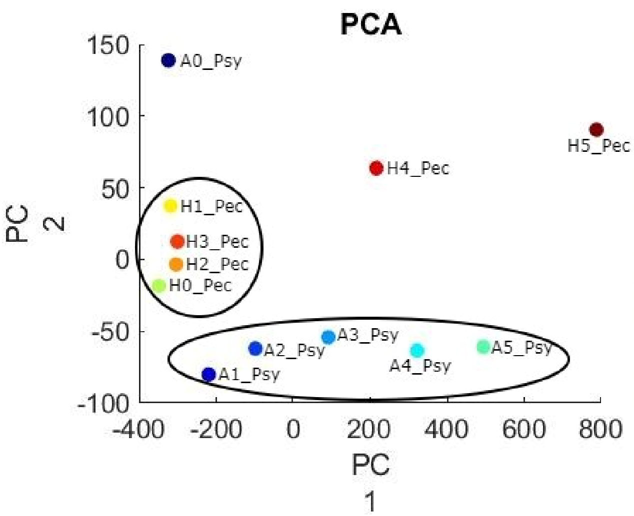

Figure 11. The PCA plot of correlation configuration of samples and characteristic attributes.

4. Conclusions

Given the results obtained from the chemical, rheological, textural, and sensory determinations, it can be concluded that a vegetable milk ice can be formulated by completely replacing the conventional stabilizer with psyllium or pectin fibers. From a technological point of view, this modification of the recipe can be allowed without hindering the technological process and without significantly changing the recipe. Ice cream with added psyllium can be obtained with a maximum of 6% added fiber and pectin fiber can be obtained with a percentage of at least 8% added in order to obtain a specific consistency and well-appreciated sensory characteristics. There is an increasing trend for the consumption of vegetable milk ice cream and through this study good results were obtained so that these formulations can be made. The increasing share of pectin added to hemp milk ice cream improved the physical properties of the ice cream, increasing the viscosity and consistency, and the appearance of the ice cream was appreciated as dense and without ice needles. It can be concluded that the almond milk ice cream was more appreciated by the panelists from a sensory point of view, while the hemp milk ice cream is more advantageous from a physical-chemical and rheological points of view due to the addition of pectin fibers. It is known that the choice of ice cream is determined primarily by taste preferences. Thus, the taste preferences for different types ice cream (almond and hemp milk) with great characteristics, which can be considered as possible applications of vegan ice cream, were investigated. Although a conflict between taste preferences and health objectives can be detected, such an approach can be treated as the main objective for a potential producer.

Author Contributions: Author Contributions: Conceptualization, A.L. and S.R.; methodology, A.L.; software, S.R.; validation, A.L., S.R. and C.G.; formal analysis, A.L. and S.R.; investigation, A.L. and S.R.; resources, A.L. and S.R.; data curation, S.R. and C.G.; writing—original draft preparation, A.L. and S.R.; writing—review and editing, A.L. and S.R.; visualization, A.L. and S.R.; supervision, C.G.; funding acquisition, A.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by “Stefan cel Mare” University of Suceava.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: This research was supported by “Stefan cel Mare” University of Suceava.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Soukoulis, C.; Lebesi, D.; Tzia, C. Enrichment of ice cream with dietary fibre: Effects on rheological properties, ice crystallization and glass transition phenomena. *Food Chem.* **2009**, *115*, 665–671. [CrossRef]
2. Rana, J.; Paul, J. Consumer behavior and purchase intention for organic food: A review and research agenda. *J. Retail. Consum. Serv.* **2017**, *38*, 157–165. [CrossRef]
3. Tsai, S.-Y.; Tsay, G.J.; Li, C.-Y.; Hung, Y.-T.; Lin, C.-P. Assessment of Melting Kinetics of Sugar-Reduced Silver Ear Mushroom Ice Cream under Various Additive Models. *Appl. Sci.* **2020**, *10*, 2664. [CrossRef]
4. Eurostat. Available online: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210803-1 (accessed on 18 January 2022).
5. Velotto, S.; Parafati, L.; Ariano, A.; Palmeri, R.; Pesce, F.; Planeta, D.; Alfeo, V.; Todaro, A. Use of stevia and chia seeds for the formulation of traditional and vegan artisanal ice cream. *Int. J. Gastron. Food Sci.* **2021**, *26*, 100441. [CrossRef]
6. Aydar, E.F.; Tutuncu, S.; Ozcelik, B. Plant-based milk substitutes: Bioactive compounds, conventional and novel processes, bioavailability studies, and health effects. *J. Funct. Foods* **2020**, *70*, 103975. [CrossRef]
7. Smeriglio, A.; Mandalari, G.; Bisignano, C.; Filocamo, A.; Barreca, D.; Bellocco, E.; Trombetta, D. Polyphenolic content and biological properties of Avola almond (*Prunus dulcis* Mill. DA Webb) skin and its industrial byproducts. *Ind. Crops Prod.* **2016**, *83*, 283–293. [CrossRef]
8. Nissen, L.; di Carlo, E.; Gianotti, A. Prebiotic potential of hemp blended drinks fermented by probiotics. *Food Res. Int.* **2020**, *131*, 109029. [CrossRef]
9. Sethi, S.; Tyagi, S.K.; Anurag, R.K. Plant-based milk alternatives an emerging segment of functional beverages: A review. *J. Food Sci. Technol.* **2016**, *53*, 3408–3423. [CrossRef] [PubMed]

10. Chalupa-Krebzdak, S.; Long, C.J.; Bohrer, B.M. Nutrient density and nutritional value of milk and plant-based milk alternatives. *Int. Dairy J.* **2018**, *87*, 84–92. [CrossRef]
11. Szparaga, A.; Tabor, S.; Kocira, S.; Czerwińska, E.; Kuboń, M.; Płóciennik, B.; Findura, P. Survivability of probiotic bacteria in model systems of non-fermented and fermented coconut and hemp milks. *Sustainability* **2019**, *11*, 6093. [CrossRef]
12. Paul, A.A.; Kumar, S.; Kumar, V.; Sharma, R. Milk Analog: Plant based alternatives to conventional milk, production, potential and health concerns. *Crit. Rev. Food Sci. Nutr.* **2020**, *60*, 3005–3023. [CrossRef]
13. Pool-Zobel, B.L. Inulin-type fructans and reduction in colon cancer risk: Review of experimental and human data. *Br. J. Nutr.* **2005**, *93*, S73–S90. [CrossRef] [PubMed]
14. McRorie, J.W., Jr.; McKeown, N.M. Understanding the physics of functional fibers in the gastrointestinal tract: An ev-idence-based approach to resolving enduring misconceptions about insoluble and soluble fiber. *J. Acad. Nutr. Diet.* **2017**, *117*, 251–264. [CrossRef]
15. Manzoor, M.F.; Siddique, R.; Hussain, A.; Ahmad, N.; Rehman, A.; Siddeeg, A.; Yahya, M.A. Thermosonication effect on bioactive compounds, enzymes activity, particle size, microbial load, and sensory properties of almond (*Prunus dulcis*) milk. *Ultrason. Sonochem.* **2021**, *78*, 105705. [CrossRef] [PubMed]
16. Leahu, A.; Ghinea, C.; Damian, C. The influence of inulin and psyllium addition to ice-cream and its effects on the sensorial properties. *Food Environ. Saf.* **2019**, *17*, 363–371.
17. Yu, B.; Zeng, X.; Wang, L.; Regenstein, J.M. Preparation of nanofibrillated cellulose from grapefruit peel and its application as fat substitute in ice cream. *Carbohydr. Polym.* **2021**, *254*, 117415. [CrossRef]
18. Espinoza, L.A.; Purriños, L.; Centeno, J.A.; Carballo, J. Chemical, microbial and sensory properties of a chestnut and milk ice cream with improved healthy characteristics. *Int. J. Food Prop.* **2020**, *2*, 2271–2294. [CrossRef]
19. Aboulfazli, F.; Salihin, A.; Misran, M. Effect of Vegetable Milks on the Physical and Rheological Properties of Ice Cream. *Food Sci. Technol. Res.* **2014**, *20*, 987–996. [CrossRef]
20. AOAC. *Official Methods of Analysis of the Association of Official Analytical Chemists*; Association of Official Analytical Chemists: Gaithersburg, MD, USA, 2000; Volume 9.
21. AOAC. Hydrogen-Ion Activity (pH). In *Official Methods of Analysis*; Association of Official Analytical Chemists: Gaithersburg, MD, USA, 1990.
22. AOAC International. 41.1.28A AOAC Official Method 996.06 Fat (Total, Saturated, and in Foods. Hydrolytic Extraction Gas Chromatographic Method Unsaturated). In *Official Methods of Analysis of AOAC International*; AOAC International: Arlington, TX, USA, 2001.
23. Karaca, O.B.; Güven, M.; Yasar, K.; Kaya, S.; Kahayoglu, T. The functional, rheological and sensory characteristics of ice creams with various fat replacers. *Int. J. Dairy Technol.* **2009**, *62*, 93–99. [CrossRef]
24. Herald, T.J.; Aramouni, F.M.; Mahmoud, A.-G. Comparison study of egg yolks and egg alternatives in French vanilla ice cream. *J. Texture Stud.* **2008**, *39*, 284–295. [CrossRef]
25. Varela, P.; Pintor, A.; Fiszman, S. How hydrocolloids affect the temporal oral perception of ice cream. *Food Hydrocoll.* **2014**, *36*, 220–228. [CrossRef]
26. Kozłowicz, K.; Nazarewicz, S.; Różyło, R.; Nastaj, M.; Parafiniuk, S.; Szmigielski, M.; Bieńczak, A.; Kozłowicz, N. The Use of Moldavian Dragonhead Bagasse in Shaping the Thermophysical and Physicochemical Properties of Ice Cream. *Appl. Sci.* **2021**, *11*, 8598. [CrossRef]
27. Hua, Z.; Jianle, C.; Junhui, L.; Chaoyang, W.; Xingqian, Y.; John, S.; Shiguo, C. Pectin from citrus canning wastewater as potential fat replacer in ice cream. *Molecules* **2018**, *23*, 925.
28. Makinen, O.E.; Wanhalinna, V.; Zannini, E.; Arend, T.E.K. Foods for special dietary needs: Non-dairy plantbased milk substitutes and fermented dairy type products. *Crit. Rev. Food Sci. Nutr.* **2016**, *56*, 339–349. [CrossRef] [PubMed]
29. Elsamani, M.O. Probiotics, organoleptic and physicochemical properties of vegetable milkbased bio-ice cream supplemented with skimmed milk powder. *Int. J. Nutr. Food Sci.* **2016**, *5*, 361–366. [CrossRef]
30. Shinyoung, K.; Stephen, L.M.; Juan, L.S.; Wesley, S.M.; Lurdes, S.W. Sensory and nutritional characteristics of concept frozen desserts made from underutilized sweetpotato roots. *Hort.Technol.* **2021**, *31*, 259–265.
31. Adapa, S.; Dingeldein, H.; Schmidt, K.A.; Herald, T.H. Rheological properties of ice cream mixes and frozen ice creams containing fat and fat replacers. *J. Dairy Sci.* **2000**, *83*, 2224–2229. [CrossRef]
32. Dervisoglu, M.; Yazici, F.; Ayedemir, O. The effect of soy protein concentrate addition on the physical, chemical, and sensory properties of strawberry flavored ice cream. *Eur. Food Res. Technol.* **2005**, *221*, 466–470. [CrossRef]
33. Muse, M.R.; Hartel, R.W. Ice cream structural elements that affect melting rate and hardness. *J. Dairy Sci.* **2004**, *87*, 1–10. [CrossRef]
34. Mahdian, E.; Karazhian, R. Effects of Fat Replacers and Stabilizers on Rheological, Physicochemical and Sensory Properties of Reduced-fat Ice Cream. *JAST* **2013**, *15*, 1163–1174.
35. David-Birman, T.; Romano, A.; Aga, A.; Pascoviche, D.; Davidovich-Pinhas, D.; Lesmes, U. Impact of silkworm pupae (*Bombyx mori*) powder on cream foaming, ice cream properties and palatability. *Innov. Food Sci. Emerg. Technol.* **2022**, *75*, 102874. [CrossRef]