Article

The Use of Moldavian Dragonhead Bagasse in Shaping the Thermophysical and Physicochemical Properties of Ice Cream

Katarzyna Kozłowicz ¹ , Sybilla Nazarewicz ² , Renata Różyło ^{3,*} , Maciej Nastaj ⁴ , Stanisław Parafiniuk ⁵ , Marek Szmigielski ¹, Agata Bieńczyk ⁶ and Natalia Kozłowicz ⁷

- ¹ Department of Biological Bases of Food and Feed Technology, University of Life Sciences in Lublin, Głęboka 28, 20-950 Lublin, Poland; katarzyna.kozlowicz@up.lublin.pl (K.K.); marek.szmigielski@up.lublin.pl (M.S.)
 - ² Department of Agricultural, Forestry and Transport Machines, University of Life Sciences in Lublin, Głęboka 28, 20-950 Lublin, Poland; sybilla.nazarewicz@up.lublin.pl
 - ³ Department of Food Engineering and Machines, University of Life Sciences in Lublin, Głęboka 28, 20-950 Lublin, Poland
 - ⁴ Department of Dairy Technology and Functional Food, University of Life Sciences in Lublin, Skromna 8, 20-704 Lublin, Poland; maciej.nastaj@up.lublin.pl
 - ⁵ Department of Machine Operation and Production Process Management, University of Life Sciences in Lublin, Głęboka 28, 20-950 Lublin, Poland; stanislav.parafiniuk@up.lublin.pl
 - ⁶ Łukasiewicz Research Network, Industrial Institute of Agricultural Machines, Starołęcka 31, 60-963 Poznań, Poland; agata.bieniczak@pimr.lukasiewicz.gov.pl
 - ⁷ Faculty of Medicine, Dental Medicine, Medical University of Lodz, Pomorska 251, 92-212 Lodz, Poland; natalia.kozlowicz@stud.umed.lodz.pl
- * Correspondence: renata.rozylo@up.lublin.pl

Citation: Kozłowicz, K.; Nazarewicz, S.; Różyło, R.; Nastaj, M.; Parafiniuk, S.; Szmigielski, M.; Bieńczyk, A.; Kozłowicz, N. The Use of Moldavian Dragonhead Bagasse in Shaping the Thermophysical and Physicochemical Properties of Ice Cream. *Appl. Sci.* **2021**, *11*, 8598. <https://doi.org/10.3390/app11188598>

Academic Editor: Andrea Salvo

Received: 29 August 2021

Accepted: 13 September 2021

Published: 16 September 2021

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Featured Application: The research presents the development of innovative ice cream based on rice milk with the addition of Moldavian dragonhead bagasse. Such a product can be put into industrial production.

Abstract: The aim of the study was to analyze the influence of bagasse from Moldavian dragonhead (*D. moldavica* L.) seeds as a source of valuable nutrients on the physicochemical properties of rice milk ice cream. The basic composition of the ice cream was modified with a varied proportion of Moldavian dragonhead bagasse (MDB) (1.0%, 1.5%, 2.0%, 2.5%, and 3.0%). The analysis of fatty acids showed a high proportion of linolenic acid (*n*-3) in the tested ice cream, especially with 3.0% share of bagasse. The addition of MDB increased dry matter, fat, and protein contents in the ice cream. The increasing share of this additive affected the physical properties of ice cream, increasing hardness, adhesiveness and viscosity, and reducing their melting rate. The study showed a negligible effect of the increasing share of MDB on the thermophysical properties of ice cream. Due to the high nutritional value of the bagasse (with the appropriate refinement of the recipe), it is possible to obtain rice milk ice cream with potential health-promoting properties.

Keywords: ice cream; physicochemical properties; Moldavian dragonhead; bagasse; sustainable development

1. Introduction

Ice cream is a valuable accompaniment to the diet for all age groups, especially for children. The quality and variety of ice cream manufacturing have gained importance in the dairy industry. Ice cream is a frozen complex colloidal system that is composed of partially coalesced fat droplets, air cells, ice crystals, and a continuous aqueous phase, wherein the polysaccharides, proteins, lactose, and minerals are dispersed. Other ingredients can be added to ice cream to confer aroma, colour, and flavour, and enhance its nutritional value and technological properties. A typical composition of ice cream consists of about 30% ice, 5% fat, 15% matrix, and 50% air by volume [1].

Moldavian balm (syn. Moldavian dragonhead) (*D. moldavica* L.) is a perennial herb belonging to the *Lamiaceae* (Labiatae) family. *D. moldavica* L. is an annual species with local (native to central Asia) and more often with global importance. *D. moldavica* L., due to its pleasant lemon scent and medical effects, has acquired increasing impact as a functional food [2–6].

Dragonhead seeds are rich in fatty oil [7,8], which content ranges from 18 to 29%. This oil is rich in unsaturated fatty acids (about 90%), principally the linolenic and linoleic acids (about 60 and 20%, respectively) which belong to essential fatty acids [9]. The average protein content of dragonhead seeds is around 21% [10]. The presence of terpenoids, flavonoids, alkaloids, lignans, phenols, coumarins, and cyanogenic glucosides has been also shown in dragonhead [11]. Different flavonoids (31) compounds were isolated from *D. moldavica* L., including flavonoids, flavonols, and flavonoids glycosides [11–13]. Among phenylpropanoids compounds in *D. moldavica* L. were found phenyl propionic acid, lignans, and coumarins [12] rosmarinic acid, and apigenin [14]. Another study [15] identified such phenolic compounds as hydroxybenzoate, hydroxycinnamates, and flavonoids. The principal constituents of essential oil of *D. moldavica* L., according to El-Baky and El-Baroty, [16] were geranyl acetate, geranial, geraniol, nerol, neryl acetate, neral, and linalool. In another study [17] oxygenated monoterpenes (96.3%) were found to be the principal group of compounds, of which neral, geranial, geranyl acetate and geraniol were the major constituents of the essential oil. According to results obtained by Fattahi et al. [18] oxygenated monoterpenes (55.4%) were the main constituents of the extracts of *D. moldavica* L.

Some authors suggest that the use of *D. moldavica* L. essential oil could provide a powerful tool in control of pathogenic microorganisms in the food and pharmaceutical industry. The antimicrobial potential of the essential oil of Egyptian Moldavian balm against six bacterial (*Bacillus subtilis*, *Bacillus cereus*, *Staphylococcus aureus*, *Micrococcus luteus*, *Klebsiella pneumoniae*, *Serratia marcescens*) and four fungal strains (*Aspergillus niger*, *Penicillium notatum*, *Mucora heimalis*, *Fusarium oxysporum*) was investigated by El-Baky and El-Baroty [16].

Jiang et al. [13] studied the antioxidative activity of total flavonoids extracted from *D. moldavica* L. The total flavonoids showed remarkable scavenging effects against 1,1-diphenyl-2-picrylhydrazyl, hydroxyl, and superoxide anion radicals in vitro.

Moldavian dragonhead (*D. moldavica* L.) is used in traditional medicine as a stimulant and antiseptic [19]. Extracts and oil from this plant are used widely in the food, pharmaceutical, flavouring, and cosmetic industries [20]. So far, the addition of *D. moldavica* L. leaves has been tested in bread [21], or corn snacks [2]. Snacks were also enriched with *D. moldavica* L. seeds [3,22]. These seeds were used in the 3, 12, and 22% snacks recipes.

Moldavian dragonhead bagasse (MDB) (Figure 1b) is waste product from the process of pressing oil from the seeds (Figure 1a) of *D. moldavica* L.

Figure 1. The appearance of seeds (a) and bagasse from *D. moldavica* L. (b).

The use of bagasse from these seeds has not yet been extensively tested in food production. Recently, MDB were just an addition to the production of pasta [23]. The addition of MDB to extruded products was also noted by Oniszczuk et al. [24].

The pasta was supplemented with MDB added to the recipe up to 25%. It was found that this waste could be used in an amount of 10% for pasta; consequently, an acceptable product with high nutritional value was obtained. There was an increase in the nutritional value of protein by 5.8%, 145% of dietary fiber, and 50% of minerals. Moreover, MDB has a good fatty acid composition with a high proportion of linolenic acid (62.21%) and linoleic acid (20.39%) [23].

D. moldavica L. bagasse after the cold oil pressing were added as supplementation to corn snacks in the amount of 5–30%. In these studies, the increasing amount of MDB had a significant effect on the physical properties of the extrudates. A decrease in the bulk density was noticed, but also an increase in the apparent density and the cutting force. Moreover, water absorption decreased and water solubility increased [24].

Sustainable development of waste management allows the use of bagasse, especially from seeds, as a source of valuable nutrients (fiber, protein, fat, minerals, vitamins and dyes) to enrich food products, especially ice cream. In the present study, for the first time, we proposed a waste additive from the pressing of dragonhead seed for the production of ice cream. The scope of the work included the determination of thermal and physicochemical properties of ice cream with this additive.

2. Materials and Methods

2.1. Materials

Five variants of ice cream mixes (1500 g each) were prepared with the following ingredients: homogenized (UHT) natural rice drink (Natumi, Troisdorf, Germany), hemp protein (Intenson, Poland), low sugar maltodextrin (Agnex, Shanghai, China), phacelia honey with blue phacelia (*Phacelia tanacetifolia* Benth.) (B. Biebrzański apiary, Poland), Moldavian dragonhead bagasse (MDB), inulin (Agnex, Białystok, Poland), emulsifier E 471 (Fooding, Shanghai, China), and sodium carboxymethyl cellulose E466 CMC (Agnex, Białystok, Poland) as stabilizer.

2.2. Production and Analysis of Bagasse

The bagasse was obtained by pressing oil from the seeds of Moldavian dragonhead (*D. moldavica* L.), which came from the farm's own cultivation in Czesławice, Poland. The crops were harvested in 2017. The seeds were pressed using a screw press with a variable nozzle having a diameter of 8 mm together with a set of Farmet DUO sieves of continuous operation. Before starting the press, it was heated to a temperature of 50 °C. After the temperature stabilized, the pressing process was started. Stabilization was achieved after pressing the oil from the mass of about 1 kg of seeds and the temperature at that time was about 60 °C. The pressing temperature was measured with an AD 20TH digital thermometer from Amarell-ama-digit. The bagasse was stored in dark containers at 5 °C for 6 days and then it was analysed for the content of saturated and unsaturated fatty acids using gas chromatography (Bruker 436GC chromatograph with FID detector) in accordance with the relevant standards [25]. The fatty acid methyl esters were separated on a BPX 70 capillary column (60 m, 0.25 mm, 25 m) with nitrogen as the carrier gas. The protein and fat content in the bagasse was also determined [26].

2.3. Ice Cream Preparation and Freezing Process

Basic ice cream recipes were added of 5 different percentages of MDB (1.0; 1.5; 2.0; 2.5; 3.0%) which determined inulin diminution (respectively 8.0, 7.5, 7.0, 6.5, 6.0%). All percentages are shown in Table 1. (The ice cream was prepared in the traditional way. Properly weighed ingredients were mixed according to the recipe. The resulting ice cream mixture was pasteurized at 69.0 °C for 20 min. Honey was added to the cooled mixture (20 °C) and, after thorough mixing, it was subjected to the maturation process at 4 °C for 24 h. The mixture prepared in this way was aerated with the use of a planetary mixer (Gerlingen, Bosch, Poland) for 20 min.

Table 1. Ice cream formulation.

Ingredients	Composition (g/100 g, w/w)				
	LW1.0	LW1.5	LW2.0	LW2.5	LW3.0
Rice drink	63.0	63.0	63.0	63.0	63.0
Hemp protein	7.5	7.5	7.5	7.5	7.5
Maltodextrin	10.0	10.0	10.0	10.0	10.0
Honey	10.0	10.0	10.0	10.0	10.0
MDB	1.0	1.5	2.0	2.5	3.0
Inulin	8.0	7.5	7.0	6.5	6.0
Emulsifier	0.3	0.3	0.3	0.3	0.3
Stabilizer	0.2	0.2	0.2	0.2	0.2

The freezing process was carried out in an ice cream maker (Ariete Galatera Compact, Varese, Italy) until the ice cream temperature was -6°C . Temperature was recorded every 1 min with a mini temperature recorder (LB-515 pellets, Germany). Based on the recorded changes in temperature over time, the freezing curves were plotted with the use of Microsoft Office Excel 2007. The cryoscopic temperature of the tested ice cream was determined according to Christodulo–Rjutov using a graphic method, consisting in drawing two tangents to the freezing curve and determining their intersection point [27]. The obtained ice cream was packed in plastic containers, tempered at -30°C (Whirlpool air freezer) for 24 h, and stored for 3 days. The physicochemical properties of the ice cream were tested on freeze-dried samples. The sample was lyophilized for 72 h at a pressure of 20 Pa and an ice condensation temperature of -64°C (ALPHA 2-4LD Plus freeze-dryer, Christ, Germany).

2.4. Chemical Analysis of Ice Cream

Dry matter, fat, protein, and ash contents were determined according to the AOAC standards [26]. The pH of the ice cream was measured with a pH meter (ELMETRON CP-401) equipped with an ERH-11 glass electrode at a temperature of 25°C . All measurements were performed in triplicate.

2.5. Physical Properties of Ice Cream

The determination of melting resistance consisted in measuring the time of appearance of the first drop and the total time of melting of a given volume of ice cream. Frozen samples (30 g) in the shape of a cone with dimensions: height 35 mm, upper diameter 35 mm, bottom diameter 25 mm, were placed on a mesh located on the funnel and beaker (at room temperature 20°C) and allowed to melt. The total melting time of the samples (in minutes) was measured from the time the first drop appeared [28].

The viscosity of the tested ice cream was measured with a Kinexus Lab + rheometer (Malvern Panalytical Ltd., Malvern, UK) in a coupled cylinder system (18 mm cylinder, 1 mm gap between cylinders) using a CZ5 SW 1423 SS adapter. The tests were carried out in the range of shear rate 0–250 $[1/\text{s}]$ at room temperature.

Hardness and adhesiveness (stickiness), was carried out in accordance with the methodology of Tiwari, Sharma, Kumar, and Kaur [29], adapted to the test requirements recommended by Brookfield Engineering Laboratories. A penetration test was performed in an LFRA texture analyzer equipped with a back extrusion chamber (Brookfield Engineering Laboratories, Inc., Middleboro, Massachusetts). The chamber was filled with a mass of ice cream at a temperature of -6.0°C . Ice cream hardness was determined based on the maximum force [N] required to push the probe down to 60% of the sample height. Stickiness of the ice cream was determined by measuring a negative force while the probe was withdrawn. The following parameters were adopted for the analysis: probe diameter—12 mm, chamber diameter—30 mm, probe speed during penetration—0.1 mm/s, and pressure force—0.2 N. All measurements were performed in triplicate.

2.6. Determination of Thermophysical Properties

Frozen ice cream samples were analyzed for thermophysical properties such as thermal conductivity, heat capacity, and thermal diffusivity using the KD2 Prometer (Decagon Devices, Pullman, DC, USA) equipped with the SH-1 probe. The tests were performed in 5 replications at $-22\text{ }^{\circ}\text{C}$ [30].

2.7. Statistical Analysis

The results were statistically analyzed using StatSoft Polska STATISTICA 13.1. The significance of the differences between the mean values of the determined parameters was verified with the Tukey test. The calculations were made at the significance level of $p < 0.05$.

3. Results and Discussion

Chemical Analysis of Moldavian Dragonhead Bagasse

Moldavian dragonhead bagasse (MDB) is obtained by pressing oil from seeds contained 5.43% of fat (Table 2). MDB is characterized by unique content of fatty acids. Over 90% of the fatty acids present in these MDB are unsaturated, of which over 80% are polyunsaturated fatty acids [7]. Linolenic acid ALA 18:3 (62.21%), belonging to the omega-3 group, had the highest share in the fat fraction. Linoleic acid LA (*n*-6) 18:2 in the tested MDB constituted more than 20% of fatty acids, and the content of oleic acid (*n*-9) 18:1 was approximately 10%. Similar results were obtained by Abdel-Raheem [31], Matwijczuk [7], and Stuchlik and Žak [32]. Comparing the obtained results, e.g., with high-linolenic oils, such as linseed oil and chia, the content of linolenic acid in MDB was higher than in linseed (50%) and chia (62%) oils. The *n*-3 to *n*-6 ratio (3.5) was higher than that of flax (3.3) and chia (3.2) oils [7]. The human body cannot synthesize linolenic acid, and therefore, it is known, along with linoleic acid, as an essential fatty acid. Due to the high content of this fatty acid and high ratio of *n*-3/*n*-6, Moldavian dragonhead seed, the extracted oil, and bagasse can be used as a food supplement, where enrichment with omega-3 fatty acids is needed. MDB contained 23.97% protein. According to Hanczkowski et al. [33] the seeds of the blue variety of *D. moldavica* L. contain approx. 21.03% protein, 24.02% fat, 11.23% fiber, and 4.91% ash. Protein is characterized by a favourable amino acid composition and high nutritional value. It contains a lot of sulphur amino acids (methionine and cystine) [33].

Table 2. Chemical composition of MDB.

Fatty Acid	Content [%]
Protein	23.97 ± 0.221
Fat	5.43 ± 0.120
Palmitic acid 16:0	5.83 ± 0.843
Stearic acid 18:0	2.05 ± 0.581
Oleic acid (<i>n</i> -9) 18:1	9.86 ± 0.214
Linoleic acid (<i>n</i> -6) 18:2	20.39 ± 0.672
Linolenic acid (<i>n</i> -3) 18:3	62.21 ± 0.810

The chemical composition of ice cream enriched with MDB is presented in Table 3. The obtained ice cream had a high dry matter content, ranging from $40.56\text{ g (100 g)}^{-1}$ to $41.02\text{ g (100 g)}^{-1}$. Increasing the dry matter content in the ice cream mixture reduces the diameter of the ice crystals, which is very desirable and improves the consistency of the ice cream. In addition, the dry matter content affects the degree of aeration in ice cream [34]. In general, formulations with a high dry matter content produce a better quality ice cream. According to Clarke [1], typical ice cream should contain between 28% and 40% dry matter with a fat content between 7 and 15%. However, according to Goff and Hartel [35], low fat ice cream should contain dry matter in the range of 28–32% with a milk fat content of 2–5% and in the case of light ice cream, dry matter is in the range of 30–35% with a fat content of min. 5–7%.

Table 3. Chemical composition of ice cream with the addition of MDB.

Properties	LW1.0	LW1.5	LW2.0	LW2.5	LW3.0
Dry matter [g (100 g) ^{−1}]	40.56 ± 0.031 ^a	40.56 ± 0.520 ^a	40.76 ± 0.331 ^a	41.25 ± 0.570 ^a	41.02 ± 0.180 ^a
Fat [g (100 g) ^{−1}]	2.19 ± 0.020 ^a	2.20 ± 0.013 ^a	4.08 ± 0.021 ^b	4.58 ± 0.021 ^c	5.33 ± 0.010 ^d
Protein [g (100 g) ^{−1}]	10.16 ± 0.013 ^b	10.66 ± 0.321 ^c	11.40 ± 0.042 ^a	11.66 ± 0.032 ^a	12.07 ± 0.021 ^d
Ash [g (100 g) ^{−1}]	1.97 ± 0.124 ^{ab}	1.73 ± 0.024 ^c	1.95 ± 0.044 ^{ab}	1.85 ± 0.022 ^{ac}	2.06 ± 0.021 ^b
pH	5.88 ± 0.012 ^a	5.80 ± 0.011 ^b	5.86 ± 0.013 ^{ab}	5.88 ± 0.043 ^a	5.84 ± 0.024 ^{ab}

^{abcd} Means in the same line indicated by different letters were significantly different (p value < 0.05). The results are expressed as mean ± SD ($n = 3$).

The protein content in the ice cream supplemented with MDB changed significantly ($p < 0.05$) from 10.16 g (100 g)^{−1} for the LW1.0 sample to 12.07 g (100 g)^{−1} for ice cream with 3.0% MDB addition. The importance of protein in ice cream is justified by the ability of this compound to stabilize the emulsions after the homogenization process. Proteins also have a large influence on the water-holding capacity of products, improving the viscosity of the mixtures, reducing ice formation, and increasing the melting resistance of ice creams [1]. According to Clarke [1], standard ice cream generally has a protein content of around 4–5%, lower than the values obtained in the present study.

The fat content of ice cream samples is given in Table 3. All results differed significantly ($p < 0.05$) from each other. That with the increase in the percentage of MDB in the ice cream, the content of fat and fatty acids increases significantly (Table 4). These values for fat ranged from 2.19 g (100 g)^{−1} (LW1.0) to 5.33 g (100 g)^{−1} (LW3.0). The fat content affects the degree of aeration in the ice cream. Many authors define fat content limits in cream ice cream at the level of 8 and 12%, at which the best air entrainment effect is obtained [1,35]. The ratio of fat content to dry matter content is also important and depends on the type of ice cream. For ice cream made with sucrose, the fat content is three times less than the dry matter content with 70% aeration, and for ice cream with inulin the fat content is almost five times less than the dry matter content with 43% aeration [36].

Table 4. Fatty acid content of ice cream with the addition of MDB.

Properties	LW1.0	LW1.5	LW2.0	LW2.5	LW3.0
Palmitic acid [%]	0.05 ± 0.001 ^a	0.08 ± 0.010 ^b	0.11 ± 0.010 ^c	0.14 ± 0.010 ^d	0.16 ± 0.010 ^e
Stearic acid [%]	0.02 ± 0.010 ^a	0.03 ± 0.013 ^{ab}	0.04 ± 0.014 ^{ab}	0.05 ± 0.013 ^{ab}	0.06 ± 0.021 ^b
Oleic acid [%]	0.10 ± 0.001 ^a	0.15 ± 0.000 ^b	0.20 ± 0.001 ^c	0.24 ± 0.011 ^d	0.30 ± 0.011 ^e
Linoleic acid [%]	0.21 ± 0.011 ^a	0.31 ± 0.011 ^b	0.41 ± 0.010 ^c	0.51 ± 0.022 ^d	0.61 ± 0.020 ^e
Linolenic acid [%]	0.62 ± 0.01 ^a	0.93 ± 0.01 ^b	1.24 ± 0.02 ^c	1.56 ± 0.08 ^d	1.87 ± 0.02 ^e

^{abcde} Means in the same line indicated by different letters were significantly different (p value < 0.05). The results are expressed as mean ± SD ($n = 3$).

As verified in Table 3, the ash content for all the ice cream formulations were similar; however, ice cream sample LW3.0 contained higher amounts (2.06 g (100 g)^{−1} ($p < 0.05$).

The effect of addition of MDB on the pH ice cream presented in Table 3. pH value ranged between 5.80 and 5.88 and it was observed that the increasing proportion of MDB did not cause significant changes in the pH of the ice cream. The obtained pH values were lower than those obtained by other authors of the studies, 6.27–6.52 [37], 6.17–6.48 [38], and 6.65–7.05 [39].

Supplementation of ice cream with MDB also influenced the physical properties of ice cream. The selected features are presented in Table 5. The study of the time of the first drop appearance and the total melting time showed statistically significant differences ($p < 0.05$) for the examined ice cream. The ice cream with a 3% share of MDB had the highest melting time (the total melting time was 38 min). The obtained values of 34.74–38.00 min indicate the high melting resistance of ice cream [40]. Melting characteristics are an important parameter in assessing the quality of ice cream, the correct selection of technology and freezing parameters. The melting point is determined by a number of parameters, such as

the dry matter content, the size of ice crystals, the number and size of fat particles, as well as the composition of the ice cream mixture [41].

Table 5. Physical properties of the tested samples.

Properties	LW1.0	LW1.5	LW2.0	LW2.5	LW3.0
First drop [min]	8.65 ± 0.812 ^c	11.19 ± 1.021 ^a	11.53 ± 0.491 ^a	12.20 ± 0.954 ^{ab}	13.94 ± 0.961 ^b
Complete melting time [min]	34.74 ± 0.672 ^a	35.56 ± 0.391 ^a	35.83 ± 0.474 ^{ab}	37.35 ± 0.744 ^{bc}	38.00 ± 0.620 ^c
Hardness [N]	9.25 ± 0.173 ^b	11.60 ± 1.232 ^c	15.77 ± 0.901 ^a	15.74 ± 0.463 ^a	28.76 ± 0.681 ^d
Adhesiveness [N·s]	−15.72 ± 0.732 ^e	−21.63 ± 0.773 ^d	−27.46 ± 0.502 ^c	−32.89 ± 1.221 ^b	−44.47 ± 1.420 ^a

^{abcde} Means in the same line indicated by different letters were significantly different (p value < 0.05). The results are expressed as mean ± SD ($n = 3$).

The hardness of the tested ice cream differed statistically significantly ($p < 0.05$) and ranged from 9.25 N to 28.76 N. The highest hardness was recorded for ice cream with a 3.0% share of MDB (LW3.0) (Table 5). Increasing the percentage of this additive in ice cream resulted in an increase in their hardness. Similar relationships were observed for the adhesiveness (stickiness). Adhesiveness is defined as the work necessary to overcome the attractive forces between the surface of the food product and the surface of other materials with which it comes in contact. Ice cream with a 1.0% share of MDB (LW1.0) had the lowest adhesiveness (−15.72 N·s), while that with a 3.0% share the highest (−44.47 N·s). Numerous factors such as the ingredients used [42,43], fat network, ice phase volume, ice crystal content and ice crystal size [41] influence hardness. The effect of fat content and gum concentration on the adhesiveness of sample was found parallel to the results of the hardness; that may be due to change in ice phase volume, viscosity and texture [43]. The similar trend for these parameters was reported by other researchers [44,45].

Apparent viscosity is a physical property of ice cream. According to Goff and Hartel [35] viscosity is especially important for industry design but there is not a clear optimum value for viscosity. Figure 2 shows the viscosity values for the five tested ice cream samples at variable speed. The study on the viscosity of ice cream with the addition of MDB showed non-linear characteristics, i.e., samples exhibited pseudoplastic behavior. The LW3.0 and LW2.5 samples showed the greatest decrease in viscosity for low speed gradients, while the LW1.0 and LW1.5 samples showed a very low initial viscosity value of 3.2 and 6.6 Pa·s, respectively. The increase in viscosity along with the increase in the proportion of MDB in ice cream may be caused by the presence of fiber. El Nagar et al. [46] noted that the increase in viscosity in low-fat ice cream with the addition of inulin may cause interactions between the dietary fiber and water as a component of the ice cream mixture.

Table 6 shows the values of the cryoscopic temperature and thermophysical properties (thermal conductivity— λ , heat capacity— C , thermal diffusivity— a) of ice cream with different percentages of bagasse from *D. moldavica* L. seeds. The cryoscopic temperature of the tested samples did not differ statistically significantly and ranged from −3.5 °C to −4.0 °C. This parameter is one of the most important thermophysical properties of food. It is necessary to determine its value when designing and optimizing refrigeration technologies [47–49].

The ice cream containing 2.5% (LW2.5) of MDB had a lower conductivity coefficient ($1.06 \text{ W} \cdot (\text{m} \cdot \text{K})^{-1}$) than ice cream with the share of 1.0% (LW1.0). The highest value of heat capacity ($C = 2.72 \text{ MJ} \cdot (\text{m}^3 \cdot \text{K})^{-1}$) was recorded for the sample with 1% addition of MDB (LW1.0). Agrawal et al. [50] reported that thermal conductivity of ice cream ranged from $1.039 \text{ W} \cdot (\text{m} \cdot \text{K})^{-1}$ to $1.071 \text{ W} \cdot (\text{m} \cdot \text{K})^{-1}$ and heat capacity values from $2.516 \text{ MJ} \cdot (\text{m}^3 \cdot \text{K})^{-1}$ to $2.542 \text{ MJ} \cdot (\text{m}^3 \cdot \text{K})^{-1}$. Thermal diffusivity for ice cream containing 3.0% (LW3.0) MDB was significantly higher than the other tested samples and amounted to $0.50 \text{ mm}^2 \cdot \text{s}^{-1}$. The main factor influencing the thermophysical properties is the amount of frozen water, which also depends on the final temperature of the product.

Figure 2. The influence of shear rate on the change in the viscosity of ice cream with MDB.

Table 6. Thermophysical properties of the tested ice cream.

Properties	LW1.0	LW1.5	LW2.0	LW2.5	LW3.0
Cryoscopic temperature T_{cr} [°C]	-3.50 ± 0.000^a	-3.50 ± 0.000^a	-3.50 ± 0.000^a	-4.00 ± 0.000^b	-4.00 ± 0.000^b
Thermal conductivity λ [$W \cdot (m \cdot K)^{-1}$]	1.10 ± 0.021^c	1.08 ± 0.014^{abc}	1.09 ± 0.013^{bc}	1.06 ± 0.011^a	1.07 ± 0.014^{ab}
Heat capacity C [$MJ \cdot (m^3 \cdot K)^{-1}$]	2.72 ± 0.101^d	2.57 ± 0.042^a	2.55 ± 0.051^a	2.40 ± 0.081^c	2.17 ± 0.032^b
Thermal diffusivity a [$mm^2 \cdot s^{-1}$]	0.40 ± 0.012^a	0.41 ± 0.051^a	0.42 ± 0.001^a	0.44 ± 0.010^a	0.50 ± 0.001^b

^{abcd} Means in the same line indicated by different letters were significantly different (p value < 0.05). The results are expressed as mean $\pm$ SD ($n = 3$).

4. Conclusions

The analysis of ice cream showed a high proportion of linolenic acid ($n-3$) in the tested samples, especially with 3.0% share of MDB. Supplementation with MDB increased the content of dry matter, fat, and protein in ice cream. The growing share of MDB affected the physical properties of ice cream, increasing adhesiveness and viscosity, and reducing their melting rate. The increasing share of MDB in ice cream resulted in an unfavorable increase in its hardness. At the same time, it did not have a significant influence on the thermophysical properties of ice cream. However, taking into account the general evaluation of the ice cream, it was found that the increasing share of MDB in the ice cream deteriorated its color and gave it a bitter aftertaste. Hence, the 1% share of MDB was the most acceptable. However, taking into account the nutritional value of MDB (if the recipe is properly developed), it is possible to obtain rice milk ice cream with potential health-promoting properties, which may have a beneficial effect on the consumer's health.

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

Funding: The research was financed by the “Excellent science” program of the Ministry of Education and Science as a part of the contract no. DNK/SP/465641/2020. The role of the agricultural engineering and environmental engineering in the sustainable agriculture development.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Correspondence and requests for materials should be addressed to R.R.

Conflicts of Interest: The authors declare no potential conflict of interest concerning the research, authorship, and/or publication of this article.

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