

STUDY OF THE PROPERTIES OF VEGAN ICE CREAM BASED ON ALMOND DRINK

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Summary. The objective of this study was to create a formula of vegan ice cream based on almond drink with the same unitary operations applied for the milk ice cream. Additionally, the influence of selected stabilizers on the physical, organoleptic characteristics of ice cream and crystal structure was studied. A mixture of two stabilizers locust bean gum (LBG) and xanthan gum was applied. The obtained results showed that the addition of stabilizers had no significant effect on the physical parameters of ice cream. However, the addition prevented recrystallization and the ice crystal equivalent diameter did not exceed 21 μm . The organoleptic evaluation the ice cream with stabilizers obtained the highest score. In conclusion, this paper showed that the same parameters and additives could be used equally for milk and vegan production of ice cream.

Key words: vegan ice cream, almond drink, stabilizers

INTRODUCTION

The appropriate composition of ice cream and the interactions between ingredients contribute to obtain the positive characteristic structure of ice cream a desert appreciated by most consumers. During the final production steps, storage and commercialization of ice cream, undesirable changes might occur that have a negative impact on their structure [Kamińska-Dwórznicza et al. 2019, Lomolino et al. 2020]. As a result of the temperature fluctuation, the sizes of ice crystals change, which leads to the phenomenon of recrystallization, which results in product degradation [Gaukel et al. 2014]. To inhibit recrystal-

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lization processes a good way is to add substances that have a preventive effect on the ice crystals growth, called stabilizers [Kamińska-Dwórznička et al. 2013]. The main reason for using of stabilizers in the freezing process is their ability to increase the viscosity of the solution, which could lead to the limitation of water molecules migration during storage [Soukoulis et al. 2008, Goff and Hartel 2013]. Although cow's milk is an important source of nutrients, many people suffer from cow's milk allergy and lactose intolerance. Additionally, the consumers choose plant's products, instead of milk ones because of other factors such as the presence of cholesterol, health and environment consideration [Kundu et al. 2018, Vanga and Raghavan 2018]. The solution to this problematic issue can be the consumption of almond drink instead of cow's milk [Vanga and Raghavan 2018]. Almond has a relatively high number of phytochemicals (including phenolic acids, phytosterols), polyphenolic compounds (flavonoids and pro-anthocyanidins), vitamin E, monounsaturated and polyunsaturated fatty acids, arginine and potassium. Due to this beneficial nutrient profile, almond has antioxidant and anti-inflammatory properties and it can reduce cardiovascular diseases risk [O'Neil et al. 2016, Yüksel et al. 2017].

This study aimed to prepare the initial formula for vegan ice cream. Besides this, the recipe was prepared accordingly with the milk ice cream production. Moreover, the addition of two stabilizers was compared with the sample with any additions, on the physical and sensory properties of obtained ice cream.

MATERIAL AND METHODS

Materials

The following ingredients were used for preparing the best options of vegan ice cream production: roasted almond original (Alpro), almond syrup (Monin), saccharose (Diamant Cukrownia Glinojek), glucose (Biomus), inulin (Orafti BENEEO), pea protein (Natural YS S85F, Roguette), emulsifier E471 (Fooding Shanghai), milk powder without lactose (Mlekovita) – eliminate from the final formula, LBG (Fooding Shanghai), xanthan gum (Fooding Shanghai).

Ice cream production

The development of the final formula required preliminary testing, during which seven other recipes were tested. Ultimately, from the seventh tried one was finally the basic for the ice cream production (Table 1). All ingredients were weighed separately with a determined formula. Then dry components were mixed with the liquid ones, using Bosch MaxoMixx 750W blender. The Vorwerk thermomixer was used for pasteurization process of the ice cream mix at 95°C per 1.5 min. Afterwards, the mix was cooled to 25°C, and frozen through 40 min using the ice cream maker Nemox Gelato Pro 1700 (Nemox, Italy). Then the samples were placed into a plastic boxes and hardened at -18°C for 24 h. In the meantime, a control sample of ice cream without any stabilizers (WOS)

was prepared. All the physical measurements for control sample and for the sample with the stabilizers addition (WS) were carried out twice. Only organoleptic analysis was carried out three times out.

Table 1. Final formula of vegan ice cream

Tabela 1. Finalna receptura lodów wegańskich

Ingredients Składniki	Weight Udział wagowy [g]	Percentage Udział procentowy [%]
Almond drink Napój migdałowy	587.36	73.42
Almond syrup Syrup migdałowy	64.00	8.00
Inulin Inulina	96.00	12.00
Pea protein Białko grochu	48.00	6.00
Emulsifier E471 Emulgator E471	3.20	0.40
Locust bean gum (LBG) Mączka chleba świętojańskiego (LBG)	0.80	0.10
Xanthan gum Guma ksantanowa	0.64	0.08

Methods

pH

Ice cream pH was measured after pasteurization and cooling 25°C, using the pH-meter Elektroda Elmetron EPP3t with temperature sensor Pt-1000B, according to the device's instruction.

Density

Density was carried out using the glass pycnometer at ambient temperature, according to the method presented by Dłużewska et al. [2003]. The pycnometer was weighed on an analytical weight with an accuracy of 0.1 g. Then it was filled with ice cream mix and capped tightly and weighed on an analytical weight with an accuracy of 0.1 g.

Melting test

In order to study the ice cream melting behaviour, the method described by Dłużewska et al. [2003] was used. For this purpose, a cooled metal cylinder (of known volume) was filled with ice cream and kept at -18°C for 24 h. Then the cylinder was placed on a glass funnel so that it wasn't touching this funnel. The melting time was measured from the moment the first drop appeared in the narrowed part of the funnel.

Determination of the overrun

The overrun of the final product was determined according to the method described by Ismail et al. [2013]. A known volume of ice cream mix and ice cream after freezing was weight.

Microstructural analysis of ice crystals

Ice crystals were analyzed based on the images taken after 24 h of storage at -18°C . The first step of this determination was sampling. The small amount of ice cream was put on cool slide using a spatula and covered by a cool slip glass, at the storage temperature. The images were taken using the Nikon Alpha Phot-2 microscope with the cooling system Linkam Scientific PE 94 and camera Nikon DS.-Fi1. The obtained images were analyzed using NIS Elements D software. The 200 to 300 ice crystal were marked for a particular sample, and then the area, equivalent diameter and standard deviation were calculated using the NIS Elements D Imaging software (ver. 3.00, Nikon). The frequency distribution of crystals size was figured using Microsoft Excel 2011 macro data analysis. A method developed by Regand and Goff [2003] was applied to report the relative frequency of any class range was figured as the number of the crystals in that range (range frequency) divided by the total number of crystals.

Organoleptic evaluation

The organoleptic analysis was carried out with a group of 10 people. The analysis was conducted using the 5-point scale, for 1 – the less desirable features and 5 – the most desirable features. All the samples were prepared 24 h before and stored at -18°C . Then the ice cream samples were kept at room temperature for at least 10 min (for softening), portioned and placed into plastic cups. The group of testing panellists evaluated the following categories: taste, colour, smell, consistency and melting time.

Statistical analysis

All obtained results were processed using a one-way analysis of variance with the Tukey test at the significance level of $\alpha = 0.05$, program Statistica 13.1.

RESULTS AND DISCUSSION

The first parameter which was measured in prepared samples was the pH. In the research conducted by Fiol et al. [2017], the pH for milk ice cream with added lactose and sodium caseinate as the main ingredients, measure from 7.7 to 7.8 [Fiol et al. 2017]. These results indicate that both with (WS) or without stabilizers (WOS) ice cream had similar pH (Table 2). However, the statistical analysis indicates no significant differences between WS and WOS. According to Makinde and Adebile [2018] research, the pH of almond drink is the range from 6.53 to 6.93. Considering the composition (Table 1), the almond drink was more than 70% of ice cream and could have contributed most to the pH of the ice cream mix. Additionally, the pea protein added to both samples might have contributed in increasing of the pH. Stabilizers addition shouldn't affect the pH of ice cream.

The density of ice cream matrix varied in composition and it might be in the range from 1.0544 to 1.1232 g·ml⁻¹ [Goff and Hartel 2013]. The density increase of the ice cream mix is not a desirable factor, because it could disturb the appropriate overrun of such product [Florowska et al. 2013]. In our study there were no significant differences between the examined samples. Additionally, the density had no influence on the other physical factors like overrun or melting time (Table 2). The overrun was described as the percentage of the ice cream's expansion which is achieved from the amount of air bubbles incorporated during freezing process [Tomer and Kumar 2013]. Measured overrun values of prepared ice cream were among 26.56 and 32.02% for WS and WOS respectively. The ice cream without stabilizers (WOS) was the one characterized by a higher value of this parameter. According to the statistics, the differences was not significant ($p > 0.05$). Elsa-bie and Aboel Einen [2017] proved that the ice frozen product based on plant milk had a lower overrun (40.2–44.2%) different from those based on cow's milk (52.83%). This was affected by the lower fat amount in frozen dessert based on plant products. So, also, in our case, the addition of LBG and xanthan, contributes to the decrease of this parameter (Table 2). Moreover, it was reported that according to the study Lomolino et al. [2020], ice cream based on the vegan recipes had a lower overrun (24 and 26%) than the milk ice cream (84 and 83%). Such low overrun is connected with the lack of milk proteins. These ingredients are responsible for forming foam due to their amphiphilic character. The addition of stabilizers may increase the melting resistance because of their abilities – such as micro-viscosity enhancement or water-holding [BahramParvar et al. 2013]. In the prepared ice cream, the melting time for the WS sample with the complex of stabilizers was better than for the WOS sample. It was almost one hour – 57.08 min (Table 2). Basing on the statistical analysis, the samples were significantly different. Also, the results presented by Dłużewska et al. [2003] confirm that the addition of locust bean gum and xanthan gum as stabilizers to ice cream caused elongation in the melting time. It was probably caused by the stabilizers addition that could trap the water molecules and then in consequence extend the melting time. Based on the knowledge of the research from Akin et al. [2007], the addition of inulin had an influence on the melting time. The

Table 2. Results of physical analysis

Tabela 2. Wyniki pomiaru właściwości fizycznych

Physical properties Właściwości fizyczne	WOS	WS
pH	7.42 ^A ± 0.1250	7.34 ^A ± 0.1250
Density – Gęstość [g·cm ⁻³]	1.089 ^A ± 0.0005	1.089 ^A ± 0.0010
Overrun – Puszystość [%]	32.02 ^A ± 1.2350	26.56 ^A ± 1.3100
Melting time – Czas topnienia [min : s]	42 : 45 ^A ± 0 : 37	57 : 08 ^B ± 1 : 44

WOS – ice cream sample without the addition of stabilizers (control sample); WS – ice cream sample with the addition of stabilizers (locust bean gum, xanthan gum). Values are reported as means ± standard deviation. Various letters indicate significant ($p < 0.05$) differences in samples.

WOS – lody bez dodatku stabilizatorów (próbka kontrolna); WS – lody z dodatkiem stabilizatorów (mączki chleba świętojańskiego, gumy ksantanowej). Wyniki pomiarów przedstawione są jako średnia z ± odchyleniem standardowym. Różne litery oznaczają znaczące ($p < 0,05$) różnice w próbkach.

researchers used inulin as prebiotic ingredient in probiotic milk cream. Moreover, they showed that inulin prolonged the melting time of ice cream. Such substances due to their affinity to water molecules, could prevent free movement of water [Akin et al. 2007]. Moreover, in a study El-Nagar et al. [2002] the addition of inulin retarded the melting time of yog-ice cream based on stirred yoghurt and milk ice cream. The increasing of inulin addition in samples, reduced the rate of meltdown [El-Nagar et al. 2002].

The results of the sensory analysis depended by the people's subjective perception and by the conditions in which the experiment was conducted. The average result for all indicators in the control sample (WOS) was between 3.87 and 4.40 but for the ice cream sample (WS) was from 4.07 to 4.77 (Fig. 1). During the sensory analysis of WOS sample and WS one, the statistical differences between them, were recognized only for the melting time ($p > 0.05$). But for the other examined factors such flavor, colour and taste, the differences were not significant.

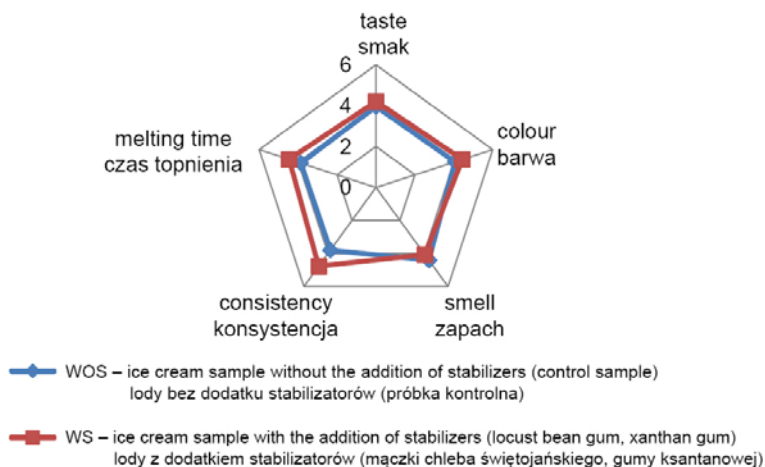


Fig. 1. Results of organoleptic evaluation

Rys. 1. Wyniki analizy organoleptycznej

There was no noticeable difference in taste for ice cream with (WS) and without stabilizers addition (WOS), however, the characteristic taste of almonds was recognized in both formulae. That phenomenon could be caused by the preference for the sweet taste. Góral et al. [2018] showed that ice cream based on coconut milk with locust bean gum is also sweeter and more acceptable by panellists. The most important impact on the prepared ice cream samples, was given by the almond drink and the pea protein. The flavour sensation was considered as acceptable and smooth. But, for the sample with locust bean gum and xanthan gum addition, this indicator was recognized as more aromatic. The colour of both samples was similar to creamy, with shades of beige and ecru. On the other hand, the WOS sample had more intensive colour than the one with the stabilizers addition (WS). Relating to the structure of ice cream, during the consumption, the WOS sample was considerably lower in consistency with higher ice crystals noticeable (Fig. 1). Based on the obtained results, the sample with stabilizers presented a longer

melting time than the sample without stabilizers. The addition of stabilizers in ice cream improve this parameter.

The ice crystals are a crucial factor which determines the quality of frozen desserts. Small size of it (10–20 μm) is required to achieve the acceptable texture of ice cream. Large ice crystals with more than 20 μm confer a coarse or grainy structure of a product [Kamińska-Dwórznička et al. 2015]. In our study, the presented images showed the structure of ice crystals after 24 h of storage at -18°C . On the first image of the WOS sample (without stabilizers) (Fig. 2a), the coalescence phenomenon was visible. The close ice crystals were linked together and made one major one. The crystals in this sample had greater size and the diameter was between 28.72 and 89.21 μm (Table 3). The shape of crystals was diverse, round and angular included. The empty spaces around them were noticed. On the images from sample with stabilizers, the shape of the crystals was regular with round edges (Fig. 2b). The ice crystals were smaller and tightly distributed. Consequently, it can be difficult to see an empty space in such structures. The obtained results showed, that its diameter had the range from 8.87 to 23.48 μm and average diameter was $17.21 \pm 1.79 \mu\text{m}$ so it was less than 25 μm .

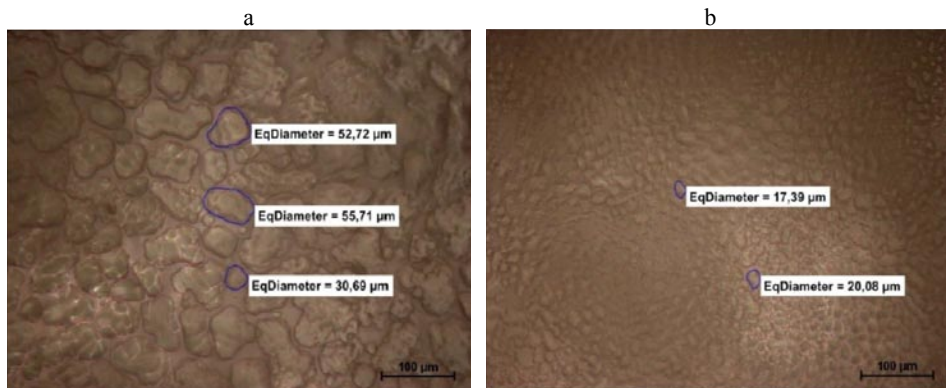


Fig. 2. Images of ice crystals in the samples after 24 h of storage at -18°C : a – WOS control sample – ice cream without the addition of stabilizers; b – WS sample – ice cream with the addition of stabilizers (locust bean gum, xanthan gum)

Rys. 2. Zdjęcia kryształów lodu w próbkach po 24 h przechowywania w -18°C : a – próbka kontrola WOS – lody bez dodatku stabilizatorów; b – próbka WS – lody z dodatkiem stabilizatorów (mączki chleba świętojańskiego, gumy ksantanowej)

Concluding on this, the recrystallization process was limited by the use of stabilizers in the composition of ice cream. Referring to organoleptic analysis, panellists did not feel sandiness in this sample and perceived a smooth and consistent texture. Lomolino et al. [2020] showed that ice cream with milk protein and stabilizers had more uniform and smaller crystals than ice cream without milk protein. Also, ice cream based on vegan protein (potato protein), had a heterogenous growth of ice crystals. In addition, the size of ice crystals was more than 20 μm [Lomolino et al. 2020]. Moreover, according to the study of Sofjan and Hartel [2004] on milk ice cream with used stabilizers: guar gum, xanthan

Table 3. Comparison of ice crystals size distribution after 24 h of storage at -18°C Tabela 3. Porównanie rozmiarów kryształów lodu po 24 h przechowywania w -18°C

Ice cream mix variant Wariant mieszanki lodowej	Ice crystals size Średnica kryształów lodu [μm]		Average diameter (D_A) in the class with the highest frequency \pm standard deviation (S_D)
	min	max	Uśredniona wartość – średnica (D_A) w klasie z największą częstotliwością \pm odchylenie standardowe (S_D)
			[μm]
WOS	28.72	89.21	51.69 \pm 1.53
WS	8.87	23.48	17.21 \pm 1.79

WOS – ice cream sample without the addition of stabilizers (control sample); WS – ice cream sample with the addition of stabilizers (locust bean gum, xanthan gum).

WOS – lody bez dodatku stabilizatorów (próbka kontrolna); WS – lody z dodatkiem stabilizatorów (mączki chleba świętojańskiego, gumy ksantanowej).

gum and carrageenan, the ice crystals size decreased when overrun increased. That means that the ice cream with lower overrun had the highest recrystallization rate. This relation can be caused by heat transfer rates upon aeration [Sofjan and Hartel 2004]. In our study, the ice cream had a lower overrun repeatedly.

CONCLUSIONS

The production of vegan ice cream based on almond drink may be conducted with the same technology as traditional milk ice cream. The physical parameters of the examined ice cream had the same or similar values as milk based ice cream. Using the LGB and xanthan gum as stabilizers in the ice cream mix lower the overrun and prolonged the melting time. Moreover, the addition of stabilizers improved the microstructure of ice cream which was also marked during the sensory analysis.

REFERENCES

- Akın M.B., Akın M.S., Kırmacı Z., 2007. Effects of inulin and sugar levels on the viability of yoghurt and probiotic bacteria and the physical and sensory characteristics in probiotic ice-cream. *Food Chem.* 104, 93–99.
- BahramParvar M., Tehrani M.M., Razavi S.M.A., 2013. Effects of a novel stabilizer blend and presence of κ -carrageenan on some properties of vanilla ice cream during storage. *Food Biosci.* 3, 10–18.
- Dłużewska E., Gazda B., Leszczyński K., 2003. Wpływ wybranych hydrokoloidów polisacharydowych na jakość koncentratów lodów owocowych. *Acta Sci. Pol. Technol. Aliment.* 2(1), 97–107.
- El-Nagar G., Clowes G., Tudorică C.M., Kuri V., Brennan C.S., 2002. Rheological quality and stability of yog-ice cream with added inulin. *Int. J. Dairy Technol.* 55(2), 89–93.
- Elsabie W.B., Aboel Einen K.A.M., 2017. New Healthy Imitated Ice Dairy Products. *J. Food Dairy Sci.* 8(6), 253–256.

- Fiol C., Prado D., Romero C., Laburu N., Mora M., Alava J.I., 2017. Introduction of a new family of ice creams. *Int. J. Gastron. Food Sci.* 7, 5–10.
- Florowska A., Wójcik E., Florowski T., Dłużewska E., 2013. Wpływ dodatku preparatów błonnikowych na wybrane wyróżniki jakości lodów. *ZPPNR* 574, 11–18.
- Gaukel V., Leiter A., Spieß W.E.L., 2014. Synergism of different fish antifreeze proteins and hydrocolloids on recrystallisation inhibition of ice sucrose solutions. *J. Food Eng.* 141, 44–50.
- Goff H.D., Hartel R.W., 2013. *Ice Cream*. 7th ed. Springer, New York.
- Góral M., Kozłowicz K., Pankiewicz U., Góral D., Kluza F., Wójtowicz A., 2018. Impact of stabilizers on the freezing process, and physicochemical and organoleptic properties of coconut milk-based ice cream. *LWT-Food Sci. Technol.* 92, 516–522.
- Ismail E.A., Al-Saleh A.A., Metwalli A.A.M., 2013. Effect of inulin supplementation on rheological properties of low-fat ice cream. *Life Sci. J.* 10(3), 1742–1746.
- Kamińska-Dwórznicza A., Antczak A., Samborska K., Pomarańska-Łazuka W., 2013. Wpływ kappa karagenu i jego hydrolizatów na proces zamrażania modelowych roztworów sacharozы. *ZPPNR* 575, 63–70.
- Kamińska-Dwórznicza A., Gondek E., Łaba S., Jakubczyk E., Samborska K., 2019. Characteristic of instrumental methods to describe and assess the recrystallization process in ice cream systems. *Foods* 8(4), 117. <https://doi.org/10.3390/foods8040117>
- Kamińska-Dwórznicza A., Matusiak M., Samborska K., Witrowa-Rajchert D., Gondek E., Jakubczyk E., Antczak A., 2015. The influence of kappa carrageenan and its hydrolysates on the recrystallization process in sorbet. *J. Food Eng.* 167(Part B), 162–165.
- Kundu P., Dhankhar J., Sharma A., 2018. Development of non diary milk alternative using soymilk and almond milk. *Food Nutr. J.* 6(1), 203–210.
- Lomolino G., Zannoni S., Zabara A., Da Lio M., De Iseppi A., 2020. Ice recrystallisation and melting in ice cream with different proteins levels and subjected to thermal fluctuation. *Int. Dairy J.* 100, 104557. <https://doi.org/10.1016/j.idairyj.2019.104557>
- Makinde F.M., Adebile T.V., 2018. Influence of processing treatments on quality of vegetable milk from almond (*Terminalia catappa*) kernels. *Act. Sci. Nutr. Health* 2(6), 37–42.
- O'Neil C.E., Nicklas T.A., Flugoni III V.L., 2016. Almond Consumption is associated with better nutrient intake, nutrient adequacy, and diet quality in adult: National health and nutrition examination survey 2001–2010. *Food Nutr. Sci.* 7, 504–515.
- Regand A., Goff H.D., 2003. Structure and ice recrystallization in frozen stabilized ice cream model systems. *Food Hydrocoll.* 17, 95–102.
- Sofjan R.P., Hartel R.W., 2004. Effects of overrun on structural and physical characteristics of ice cream. *Int. Dairy J.* 14, 255–262.
- Soukoulis Ch., Chandrinos I., Tzia C., 2008. Study of the functionality of selected hydrocolloids and their blends with κ-carrageenan on storage quality of vanilla ice cream. *LWT-Food Sci. Technol.* 41, 1816–1827.
- Tomer V., Kumar A., 2013. Development of High Protein Ice-Cream Using Milk Protein Concentrate. *IOSR-JESTFTJ* 6(5), 71–74.
- Vanga S.K., Raghavan V., 2018. How well do plant based alternatives fare nutritionally compared to cow's milk? *J. Food Sci. Technol.* 55(1), 10–20.
- Yüksel A., Şat İ., Yüksel M., Çakmakçı S., 2017. A comparative study on the physicochemical characteristics, organic acid profiles, mineral compositions and sensory properties of ice creams produced with different types of nuts. *Carpath. J. Food Sci. Technol.* 9(3), 137–151.

BADANIE WŁAŚCIWOŚCI LODÓW WEGAŃSKICH NA BAZIE NAPOJU MIGDAŁOWEGO

Streszczenie. Celem przedstawionych badań było opracowanie receptury lodów wegańskich na bazie napoju migdałowego, na podstawie procesu produkcyjnego tradycyjnych lodów mlecznych. W prezentowanych badaniach zbadano wpływ wybranych stabilizatorów na fizyczne i organoleptyczne właściwości lodów oraz strukturę kryształów po 24 h przechowywania. W tym celu przygotowano próbkę kontrolną oraz próbkę badawczą z mieszanką dwóch rodzajów stabilizatorów, tj. mączki chleba świętojańskiego (LBG) oraz gumy ksantanowej. Uzyskane wyniki wykazały, że dodatek mieszanki stabilizatorów nie wpłynął znacząco na właściwości fizyczne lodów. Dodatek stabilizatorów pozwolił zaś na ukształtowanie korzystniejszej struktury kryształów, a średnica kryształu lodu nie przekroczyła 21 μm . W ocenie organoleptycznej lody ze stabilizatorami uzyskały najwyższy wynik. W pracy wykazano, że te same parametry oraz dodatki używane w produkcji lodów mlecznych mogą być stosowane przy wytwarzaniu lodów wegańskich.

Słowa kluczowe: lody wegańskie, napój migdałowy, stabilizatory