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Effect of Aloe Vera Gel on the Physical Properties of Vegan Ice Cream Bar

Nguyet T. M. Nguyen*, Hieu T. H. Do

Institute of Biotechnology and Food Technology, Industrial University of Ho Chi Minh City, 12 Nguyen Van Bao Street, Ward 4, Go Vap District, Ho Chi Minh City, Vietnam
nguyenthiminhnguyet@iuh.edu.vn

Aloe vera is a type of crop that is easy to cultivate and highly popular in Vietnam, with a unique nutritional composition and functional characteristics that are increasingly applied in pharmaceuticals, cosmetics, and especially food. The aim of this study was to investigate the effect of aloe vera gel on the physical properties of plant-based cream such as viscosity, melting point, and structural properties. With water as the main component, accounting for 98.05 ± 0.01 %, the aloe vera gel was added to the formula of plant-based cream with mung beans and coconut milk at 0, 100, 150, 200, 250, and 300 (g). A total of 6 ice cream bar samples were studied and 1 control sample (Wall's Seru ice cream) was determined for TPA structural properties including hardness (kg), cohesion, resilience (kg), and chewiness (mJ). The results showed that the cream with 250 g of added aloe vera gel had suitable and comparable properties to Seru cream. As the proportion of aloe vera gel increased, the viscosity of the cream decreased, and conversely, the melting rate of the cream increased. Importantly, when the highest level of aloe vera gel liquid (300 g) was added, the obtained plant-based cream still had high viscosity and a slower melting time compared to the control sample of the control ice cream bar. The results of this study can be applied to the development of plant-based creams, without milk, to serve the diverse needs of customers, while reducing the adverse environmental impacts in the current global situation.

1. Introduction

Ice cream is a product that contains all food ingredients (including additives) allowed by current regulations, with a structure and texture created by freezing and stored, transported, sold, and consumed in a frozen state (Góral et al., 2018). Ice cream is a widely consumed product produced and consumed in most countries. Most types of ice cream on the market have dairy and milk as their main ingredients, providing protein and fat for the frozen product. In the ice cream-making process, the first step is to mix the appropriate amount of solid and liquid ingredients to obtain a liquid called a cream mixture. The physicochemical and sensory properties of the ice cream are determined in turn by the compositional quality of the cream mixture; it is extremely important to choose the best ingredients and focus on the characteristics of the cream mixture. The impact of dairy production, especially industrial-scale production, on greenhouse gas emissions and climate change, use of polluted water and antibiotics is great, and is estimated to be 5-10 times per unit of protein more than the impact from the production of soy-based products, other legumes, and most grains. Therefore, the environment demands a doubling of the quantity produced to meet demand. On the other hand, limiting dairy products can make a significant contribution to achieving inter-seasonal greenhouse gas goals (Willett and Ludwig, 2020). In recent years, the demand for non-dairy products has increased.
Aloe vera is a tropical succulent plant that is drought-tolerant. In botany, it is called Aloe vera (L.) Webb. (*Aloe barbadensis Mill*.) belonging to the Liliaceae family. Currently, there are more than 360 species of aloe vera known, and many studies have shown that this plant has more than 200 different biologically active components, of which more than 75 components provide health benefits and are necessary nutrients for the human body. Aloe vera has two main components, the green outer leaf, and the inner gel. Aloe vera gel has been widely used in moisturizing and soothing skin care products or pharmaceuticals (Javed, 2014). In the food industry, aloe vera gel has been used as a supplement in bread (Chopra, 2017) or as a bio-based food wrap (Shahrezaee et al., 2018). However, there is very little research on the effect of aloe vera gel on the physical properties of the

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ice cream production industry. With the development of technology and increasing demand for non-dairy ice cream products, studying the effect of aloe vera gel on the physical properties of non-dairy ice cream products is of great importance for improving and enhancing product quality. This study utilized aloe vera gel with a water content exceeding 98 % (Minjares-Fuentes et al., 2016) as a replacement for animal milk in the production of ice cream products, while also employing chickpeas for their emulsifying and gelling/hypoallergenic properties. Kot et al. (2021) noted that mung beans contain various protein components, including albumin, globulin, and minor components such as prolamin and glutelin. The study had three primary objectives: 1) to explore the processing techniques and recovery efficiency of aloe vera gel; 2) to examine the impact of aloe vera gel on cream mixture viscosity and ice cream melting characteristics; and 3) to assess the effect of aloe vera gel on the structural properties of the ice cream bar.

2. Materials and Methods

2.1 Materials

The aloe vera leaves were directly harvested from the gardens in Phu Dong commune, Nhon Trach district, Dong Nai province from November 2022 to May 2023. Mature and healthy aloe vera leaves measuring between 60-80 cm in length and weighing an average of 450-500 g were selected for the study. Green beans of a purebred small seed variety were selected. Bien Hoa refined sugar, a product of the Bien Hoa sugar factory in Dong Nai province, Vietnam, was used. Coconut milk powder and refined coconut oil are products of Luong Quoi Coconut Processing Co., Ltd. Address: Lot A36-A37, An Hiep Industrial Zone, Thuan Dien Hamlet, An Hiep Commune, Chau Thanh District, Ben Tre Province, Vietnam. CF300 (CF) was a product of Asia Shine Company. Address: 353C Nguyen Trong Tuyen, Ward 1, Tan Binh District, Ho Chi Minh City.

Wall's Seru ice cream for the control sample came from Indonesia and was is imported by Unilever Vietnam International Co., Ltd. The ice cream ingredients include water, sugar, milk powder, glucose syrup, vegetable oil, stabilizer, emulsifier, natural strawberry flavor, crushed strawberries, and synthetic coloring. The net weight of the ice cream is 43 g (equivalent to a volume of 50 mL).

2.2 Determination of aloe vera gel recovery

The aloe vera leaves with an average weight of 450-500 g were accurately weighed and washed thoroughly with clean water to remove dirt and aloin yellow sap released from the leaves after harvesting. A sharp knife was used to remove the prickly edges on both sides of the leaf and the green peel on the upper and lower surfaces of the leaf. The aloe vera flesh was then cut into 5 cm-long pieces. The aloe vera leaves were then ground to a paste using a blender (Philips HR2041/10, 450 W) for 2 min, and then filtered through a 2 mm sieve to obtain aloe vera gel extract. The weight of the gel extract obtained is recorded.

The extraction efficiency of the aloe vera gel extract was calculated using the formula as Eq(1):

$$H = \frac{m_p}{m_i} \times 100 \tag{1}$$

where: H: Recovery efficiency of aloe vera gel (%); m_p: Weight of aloe vera gel after preliminary processing (g); m_i: Initial weight of aloe leaves (g)

2.3 The properties of aloe vera gel

The viscosity of aloe vera gel was determined following the procedure outlined by Ziaeifar et al. (2018). Specifically, the viscosity was measured at 25 °C using a Brookfield viscometer, spindle number 62, with increasing shear rates ranging from 0 to 120 s^{-1}. The measurements were recorded at a shear rate of 20 s^{-1}, which was taken as the viscosity of the aloe vera gel extract.

The various properties of aloe vera gel, including moisture, total lipid, protein, crude fiber, ash, and total acid content were determined according to the guidelines set forth by TCVN. To determine moisture content, the drying method at 105 °C was employed, while the Soxhlet method with Hexane solvent was used to determine total lipid content. The Kjeldahl method was utilized to determine the protein content (N × 6.25), with samples analyzed using inorganic equipment, nitrogen distillation, and manual titration. Crude fiber content was determined in line with the TCVN 4998:1989 standard, while ash content was determined by calcination (550 °C), and total acid content was determined according to TCVN 5483:2007 with correction. The carbohydrate content was calculated by subtracting the total moisture, total lipid, protein, crude fiber, and ash from 100. The results are expressed in g per 100 g of plant material. These methods provide a comprehensive characterization of the properties of aloe vera gel, essential to understanding its potential use in non-dairy vegetable cream-based ice creams.

2.4 Steps to process aloe vera ice cream bars

Step 1. Processed the mung beans by grinding them in a versatile dry powder grinder (SEKA SK200) and then sifted them through a sieve with a mesh size of 200 µm. Weighted 50 g of the ground mung beans and mixed them with water in a ratio of 1:10 (w/w). Heated the mixture on an infrared electric stove (Sanaky SNK - 2018HG) at 2000 W, stirred continuously until the mixture boils. Reduced the power to 400 W and stirred for an additional 5 min, then turned off the stove. Added the sugar, coconut oil, coconut milk, and salt (quantified according to Table 1) in sequence and stirred for 1 min to dissolve the sugar completely. Then added CF and used a hand-held blender (Bluestone BLB5251) to homogenize the mixture for 1 min. Filtered the mixture through a sieve with a mesh size of 200 µm.
Step 2. Added aloe vera gel to the cream mixture in the proportions of formulas (FM) as shown in Table 1. Stirred the mixture with a hand-held blender (Bluestone BLB5251) for 1 min.
Step 3. Molding the Cream Bars: Used a cream bar mold with dimensions of (6.5 x 10.5 cm) and froze it in a freezer (Sanaky VH-225A2) at a temperature of - 25 °C.

Table 1: Ingredients for research mixing formula of bar creams

No.	Composition	FM 0	FM 1	FM 2	FM 3	FM 4	FM 5
1	Mung bean puree				50		
2	Water				500		
3	Aloe vera gel	0	100	150	200	250	300
4	Sugar				130		
5	Coconut powder				75		
6	Coconut oil				25		
7	CF300				4		
8	Salt				0.3		

2.5 Process of obtaining cream solution and steps to process research ice cream

The processing stages for aloe vera ice cream were summarized in Figure 1. This schematic provides an overview of the key steps and procedures involved in the manufacturing process. In this section, we delve deeper into the specific techniques and ingredients utilized, as well as the resulting properties and characteristics of the final product.

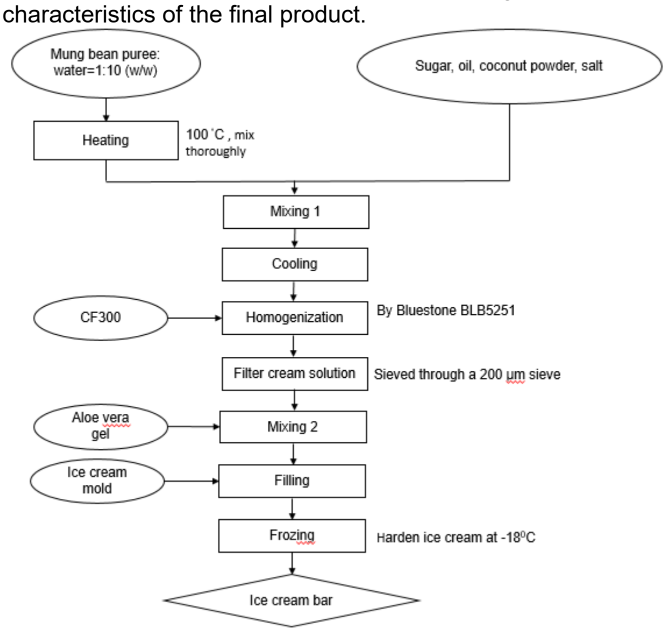

Figure 1: Process of making aloe vera ice cream bars

2.6 Determination of viscosity of ice cream bars

Viscosity measurements of the cream samples were conducted using the method of Ziaeifar et al. (2018). The apparent viscosity of the cream samples was determined at 25 °C using a Brookfield viscometer equipped with spindle No.64. Viscosity was measured at increasing shear rates ranging from 0 to 120 s^{-1}. The viscosity at a shear rate of 20 s^{-1} was considered the viscosity of the cream sample. Three measurements were conducted for each sample to obtain the average value.

2.7 Determination of melting rate of ice cream bars

The melting properties of the cream formulas were determined using the method of Cropper et al. (2013) with modifications. The cream samples (6.5 x 10.5 cm) were stored in long mold containers with lids and frozen at -25 °C before conducting the melting test. The samples were placed on a steel mesh (5 mm x 5 mm) at room temperature (32 ± 1 °C). The weight of the melted cream and the number of drips that fell into the collection tray was recorded for 60 min (as described in Figure 2).

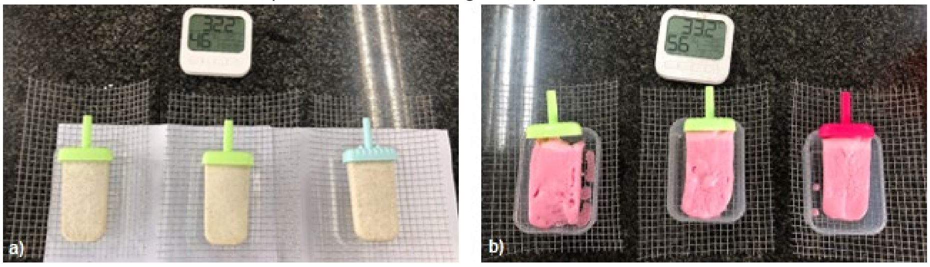

Figure 2: Experimental image to investigate the melting rate of ice cream bars (a) FM 1, (b) Wall's Seru

2.8 Determination of the structure of ice cream bars

The measurements were performed using the method of Velásquez-Cock et al. (2019) with adjustments. Before measuring, the cream samples were stored in a freezer at -25 °C overnight. A Brookfield CT3 4500 structure analyzer with a TA17 cone-shaped probe attached to a 0.45 kg load cell was used. The cream samples were chilled in the freezer and stored in an insulated container with added ice just before measuring. The cylindrical sample was 30 mm in length and 60 mm in width. A hole was made in the sample at room temperature (23 ± 1 °C) to a depth of 10 mm with a testing speed of 1.5 mm.s^{-1} to reduce variability due to sample heating. Hardness was defined as the compressive force of the probe during penetration of the cream sample. The parameters recorded included hardness (kg), cohesiveness, chewiness (kg), and resilience (mJ).

3. Results and Discussion

3.1 Investigation of recovery efficiency and some properties of aloe vera gel

The aloe vera gel post-treatment is expected to have a viscosity of (12.03 ± 0.15) cP and recovery efficiency of (50.5 ± 0.5) %, along with other relevant properties detailed in Table 2.

Table 2: The properties of the aloe vera gel

No.	Nutrients	% wt.
1	Moisture	98.05 ± 0.01
2	Total lipid	0.49 ± 0.02
3	Total protein	0.58 ± 1.01
4	Crude fiber	0.16 ± 0.01
5	Ash	0.15 ± 0.01
6	Carbohydrate	0.56 ± 0.99
7	Total acid	0.22 ± 0.10
8	pH value	4.74 ± 0.02

In comparison to the findings of Ahmad et al. (2020), our results yield similar outcomes for various parameters such as moisture content, total lipid, crude fiber, and ash content. However, some differences are observable, such as the protein content in the aqueous aloe vera gel sample being relatively high (0.58 %) compared to the 0.12 ± 0.01 % found in fresh gel (Vega-Gálvez et al., 2014). Moreover, the carbohydrate content in our experimental aloe vera sample was found to be twice as high (0.56 %) as reported by Javed in 2014 (0.25 %). These discrepancies may be attributed to differences in variable factors such as water source, temperature, and care conditions of the vegetation. Nonetheless, the value of our study lies in its contribution to the existing literature on aloe vera, expanding the knowledge of its chemical composition and paving the way for further studies in this field.

In terms of total acid content, aloe vera juice contained a significant amount of acid, measuring 0.22 g per 100 g of the sample. This was notably higher than the 0.097 g found in the study conducted by Añibarro-Ortega et al. (2019). It was possible that differences in variety and soil source may contribute to this discrepancy. The obtained pH result of 4.74 indicates that the pH level of the aloe vera water samples was not relatively high. However, Suriati et al. (2020) conducted a lower pH value of 2.16 following 4 days of storage at a temperature of 28 °C. The observed difference in pH values can be attributed to various factors such as differences in water sources as well as care conditions. Factors such as water source, soil, and care conditions can influence the above findings as seen in studies by other researchers.

3.2 Effect of aloe vera gel on the viscosity of the cream mixture and the melt-down properties of the ice cream bars

The viscosity of the cream solutions was made up of the mixing formulas shown in Table 1, and the melting rates of the respective ice cream bars were illustrated in Figure 3. Upon observing Figure 3, it becomes evident that the cream sample devoid of aloe vera displays the highest viscosity value, while the control cream, Seru, records the lowest viscosity. Amongst the cream samples containing aloe vera, the observed trend suggests a decline in viscosity as the quantity of aloe vera added increases. In light of aloe vera's intrinsic viscosity, integration of the gel into the cream formula marginally diminishes the viscosity value without causing it to become too diluted or thin. Notably, replacing aloe vera gel with water showed a marked difference compared to the control cream Seru. The cream samples' melting properties varied significantly, with Seru displaying the highest melting rate, potentially due to its high water content. As the quantity of aloe vera gel in the formula increases, the cream melts progressively faster, owing to the gel's inherently elevated water content (98 %). Conversely, the cream sample without aloe vera exhibits the lowest melting rate, primarily because the bean liquid is its primary ingredient, resulting in less liquid loss during the melting process. It ought to be noted that although the cream containing aloe vera exhibits a high melting rate, it still retains its structure and does not rapidly disintegrate like the control cream, Seru. This stability is a direct consequence of the cross-links of glucomannan that form following water loss, as identified in previous research by Suriati et al. (2020).

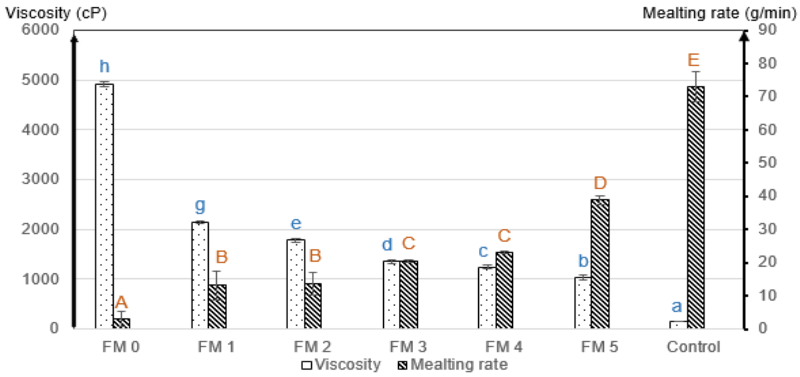

Figure 3: Effect of the mixing ratio of aloe vera gel on the viscosity of the cream solution and the melting properties of the cream.

3.3 The effect of aloe vera gel on the structural properties of the ice cream bars

This work sought to determine how the incorporation of aloe vera gel impacts the structural characteristics of non-dairy vegetable cream-based ice creams. The analytical techniques and methodology were detailed in section 2.8 of this paper, with the results presented comprehensively in Table 3. This section aims to elucidate and analyze the findings in greater depth, highlighting the key trends and insights from our study.

Table 3: The effect of the added aloe vera gel ratio on the structural properties of the ice cream bars

No.	Samples	Hardness 1 (kg)	Hardness 2 (kg)	Cohesiveness	Gumminess (kg)	Chewiness (mJ)
1	FM 0	$4.20^{bc} \pm 0.90$	$2.77^{bc} \pm 0.58$	$0.12^{ab} \pm 0.03$	$0.51^{b} \pm 0.13$	$7.73^{cd} \pm 2.82$
2	FM 1	$4.03^{bc} \pm 0.95$	$2.69^{bc} \pm 0.59$	$0.12^{ab} \pm 0.03$	$0.48^{b} \pm 0.12$	$6.69^{bcd} \pm 2.44$
3	FM 2	$4.76^{bc} \pm 0.41$	$3.16^{bc} \pm 0.18$	$0.09^{a} \pm 0.01$	$0.42^{b} \pm 0.03$	$4.30^{abcd} \pm 0.75$
4	FM 3	$5.00^{c} \pm 0.40$	$3.22^{c} \pm 0.28$	$0.07^{a} \pm 0.01$	$0.34^{ab} \pm 0.05$	$2.42^{ab} \pm 0.39$
5	FM 4	$4.27^{bc} \pm 0.64$	$3.01^{bc} \pm 0.44$	$0.12^{ab} \pm 0.05$	$0.53^{b} \pm 0.19$	$8.54^{d} \pm 5.67$
6	FM 5	$3.81^{b} \pm 0.32$	$2.50^{b} \pm 0.12$	$0.09^{a} \pm 0.02$	$0.35^{ab} \pm 0.04$	$3.47^{abc} \pm 0.85$
7	Control -Wall's Seru	$1.32^{a} \pm 0.06$	$0.78^{a} \pm 0.09$	$0.16^{b} \pm 0.07$	$0.21^{a} \pm 0.10$	$2.02^{a} \pm 1.39$

Based on Table 3, the cream samples exhibit distinct differences in structural properties, with aloe vera affecting and modifying their hardness, chewiness, and elasticity. The sample containing 200 g of aloe vera gel had the highest hardness but the lowest cohesiveness and elasticity. This phenomenon, according to Goff et al. (2013), is due to high sugar and salt concentrations resulting in a lower freezing point and less ice crystal formation, leading to a softer cream. The protein, fat, and carbohydrate content indirectly affects the cream's freezing point. This is why cream samples with less aloe vera have lower hardness, as adding aloe vera can reduce the amount of sugar, salt, and other components relative to the total volume of the cream mixture. Conversely, adding too much aloe vera can decrease the freezing point and cause surface freezing, limiting heat transfer, and resulting in softness inside the cream. Among the 5 cream samples containing aloe vera, FM4 containing 250 g of aloe vera gel had the highest cohesiveness and elasticity, making it a suitable formula for the final product.

4. Conclusions

Our study provides compelling evidence that incorporating aloe vera gel into non-dairy vegetable cream yields significant improvements in terms of various properties. The gel's inherent gelling properties are positively correlated with a reduction in the cream's melting rate when higher quantities are integrated. Also, aloe vera gel tends to impact the cream's texture and consistency in a predictable manner, with its hardness, viscosity, elasticity, and chewiness all being modulated by the mixing ratio. The final product is characterized by a soft, fluffy structure that does not melt quickly when exposed to air, with a mild and appealing sweetness. However, further research is recommended to evaluate the shelf life and antibacterial efficacy of aloe vera gel in different cream samples. Our findings suggest that aloe vera gel is a promising ingredient in improving non-dairy vegetable cream's quality and nutritional profile, opening avenues for product diversification and expansion.

References

Ahmad N., Sarfraz M., Akhtar N., Hussain K., Ahmad W., Sadique A. B., 2020, Effect of Seasonal Variation On The Recovery And Composition of Aloe Vera (Aloe Barbadensis) Gel, J. Agric. Res, 58(4), 253-259.

Añibarro-Ortega M., Pinela J., Barros L., Ćirić A., Silva S. P., Coelho E., Mocan A, Calhelha R.C., Sokovi´c M., Coimbra M. A., 2019, Compositional features and bioactive properties of Aloe vera leaf (fillet, mucilage, and rind) and flower, Antioxidants, 8(10), 444.

Chopra S. (2017). Use of aloe vera gel as a fat replacer in the preparation of cakes. Int J Agric Food Sci, 7(1), 5-11.

Cropper S. L., Kocaoglu-Vurma N. A., Tharp B. W., Harper W. J., 2013, Effects of locust bean gum and mono- and diglyceride concentrations on particle size and melting rates of ice cream, Journal of food science, 78(6), C811-C816.

Goff H. D., Hartel R. W., Goff H. D., Hartel R. W., 2013, Ice cream structure, Ice cream, 313-352.

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, 92, 516-522.

Javed S, 2014, Aloe vera gel in the food, health products, and cosmetics industry, Studies in Natural Products Chemistry, 41, 261-285.

Kot A., Kamińska-Dwórznicka A., Galus S., Jakubczyk E., 2021, Effects of different ingredients and stabilisers on properties of mixes based on almond drink for vegan ice cream production, Sustainability, 13(21), 12113.

Minjares-Fuentes R., Femenia A., Comas-Serra F., Rosselló C., Rodríguez-González V. M., González-Laredo R. F., Gallegos-Infante J.A., Medina-Torres L., 2016, Effect of different drying procedures on physicochemical properties and flow behavior of Aloe vera (Aloe *barbadensis* Miller) gel, LWT, 74, 378-386.

Shahrezaee M., Soleimanian-Zad S., Soltanizadeh N., Akbari-Alavijeh S., 2018, Use of Aloe vera gel powder to enhance the shelf life of chicken nugget during refrigeration storage, LWT, 95, 380-386.

Suriati L., Utama I. M., Harjosuwono B., Gunam I. B., 2020, Stability Aloe Vera gel as edible coating, Paper presented at the IOP Conference Series: Earth and Environmental Science.

Velásquez-Cock J., Serpa A., Vélez L., Gañán P., Hoyos C. G., Castro C., Duizer L., Goff H.D., Zuluaga R., 2019, Influence of cellulose nanofibrils on the structural elements of ice cream, Food Hydrocolloids, 87, 204-213

Vega-Gálvez, A., Miranda, M., Nuñez-Mancilla, Y., Garcia-Segovia, P., Ah-Hen, K., Tabilo-Munizaga, G., Pérez-Won, M., 2014, Influence of high hydrostatic pressure on quality parameters and structural properties of aloe vera gel (*Aloe barbadensis* Miller), Journal of Food Science Technology, 51, 2481-2489.

Willett W. C., Ludwig D. S., 2020, Milk and health, New England Journal of Medicine, 382(7), 644-654.

Ziaeifar L., Shahi M. L. M., Salami M., Askari G. R., 2018, Effect of casein and inulin addition on physico-chemical characteristics of low fat camel dairy cream, International Journal of biological macromolecules, 117, 858-862.