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Investigation of the production of low-fat dairy dessert containing postbiotics, *Aloe vera* and encapsulated crocin with balangu gum complex and sodium caseinate protein

Roghayeh Ezzati[1], Leila Roozbeh Nasiraei[1], Sara Jafarian[1], Masoud Dezyani[2], Fatemeh Shahdadi[3]

1- Department of Food Science, Nour Branch, Islamic Azad University, Nour, Iran

2- Department of Food Science, Gorgan Branch, Islamic Azad University, Gorgan, Iran

3- Department of Food Science, Faculty of Agriculture, University of Jiroft, Jiroft, Iran

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*Corresponding Author E-

ABSTRACT

Dairy dessert is a favorite product of a large group of people in society. Natural pigments can be used to improve the color and increase the nutritional value of this product. Therefore, the aim of this research is to produce a functional low-fat dairy dessert containing postbiotics, Aloe vera gel and encapsulated crocin with balangu gum complex and sodium caseinate protein. In the research, nano emulsion containing crocin (encapsulated) under optimal drying conditions and free crocin at 0.5, 1 and 1.5% along with postbiotic at 2.5, 5 and 10% were used in the formulation of dairy dessert containing Aloe Vera gel, and 18 samples were produced and characteristics such as pH, fat content, dry matter content, apparent viscosity, microbial count and sensory properties were investigated during the storage period. According to the results of this part of the research, the amount of postbiotic and nano emulsion did not affect pH ($p>0.05$). The highest fat content and viscosity were related to the sample containing 1.5% encapsulated crocin and 5% postbiotic (5.3% and 165 mPa.s), and the highest dry matter content was related to the sample containing 1.5% encapsulated crocin and 2.5% postbiotic (28.5%), and in general, the effect of encapsulated crocin on increasing fat, dry matter and viscosity was higher than that of free crocin. microbial results also showed that encapsulated crocin had a greater effect on reducing microbial load. Sensory evaluation results showed that the sample containing 1% encapsulated crocin and 2.5% probiotic had a higher overall acceptance score (5).

1- Introduction

Today, food consumers pay special attention to factors such as pleasant taste, low calorie and fat content, and the beneficial effect of food on health. Therefore, the food industry is trying to produce products that have better taste and properties, among which low-fat dairy products processed with probiotics are of great importance in promoting health (Oliviera, 2009). Dairy dessert is a product in which milk or dairy products are the main component in the formulation. The major part of the ingredients of various dairy desserts consists of dairy products including cream and butter, and non-dairy additives such as sugar, various permitted food colors, permitted flavorings, stabilizers, essential oils, or fruit marmalade form the other part of these products. The purpose of producing dairy desserts is to create variety in people's food basket, increase the consumption of useful products, and produce an enjoyable product. The most important feature of most desserts is their energy-giving property and the pleasant feeling created in the consumer due to the type of its compounds. Desserts can be consumed as a nutritional snack at any time of the day and have many fans in different age groups [1].

Postbiotics are compounds produced during the fermentation process of probiotic bacteria. When probiotics are fed with specific types of fiber molecules, they leave behind waste materials that are generally called postbiotics. The most effective and practical use is the application of the non-living form of bacteria (postbiotics) as a substitute for probiotics [2]. Postbiotics include three main parts: inactivated microbial cells (cell biomass), cell fractions (teichoic acid, muramyl peptides derived from peptidoglycan, cell surface proteins, endo- and exo-polysaccharides), as well as cell metabolites (short-chain fatty acids, enzymes, bacteriocins, and organic acids) that are secreted during the life of microbial cells or released after their decomposition in the host's intestinal environment, and if received in sufficient quantities, they exert health-promoting effects on the host [3]. Aloe vera (scientific name: Aloe vera) is a plant from the genus Aloe, order Asparagales, family Asphodelaceae, native to North Africa. Aloe vera gel, due to its composition, contains nutrients that likely help promote the growth of probiotic factors and has long been used in several countries for the treatment and prevention of gastrointestinal diseases [4]. Research has shown that in fermented products enriched with Aloe vera, the viability of probiotic bacteria Lactobacillus acidophilus and Bifidobacterium bifidum improves during the storage period [5].

Saffron has many applications in the production of food, pharmaceutical, and chemical products due to its excellent taste and color. A large part of saffron's therapeutic properties is attributed to crocin and its analogs. Crocin, as a glycosylated carotenoid, is a substance that is usually dark red in color, dissolves quickly in water, and gives it an orange-red color, thus making it useful as a natural food colorant. Crocin is also known for its antioxidant activity, trapping free radicals, and protecting cells and tissues from oxidation [6]. Given that crocin, the carotenoid pigment in saffron, is sensitive to changes in pH, temperature, and light, and this limits the color stability of products containing saffron, encapsulation techniques are used to stabilize and create stability in saffron color. Protecting and controlling the release of active compounds such as crocin, picrocrocin, and safranal leads to an increase in their efficiency [7].

Nazari and Asili (2023) investigated the physicochemical properties and release of nanoemulsion containing crocin and its application in a food model system (chocolate). The results showed that all double-layer emulsions prepared with biopolymers remained stable and did not separate into two phases over one month. Investigating the release of double-layer

emulsions in simulated stomach and intestine environment showed that the lowe
st release rate was related to samples stabilized with the biopolymer pectin and the highest was related to soy protein concentrate. Evaluation of moisture, aw, and hardness of chocolate samples showed that enriched samples had higher hardness, water activity, and moisture compared to the control sample. Sensory evaluation of the samples showed that the enriched sample obtained a significantly higher score [10]. In a study, water-soluble crocin was produced by microencapsulation via spray drying using maltodextrin as the wall material. Saffron before and after microencapsulation was examined for physicochemical properties (moisture content and color values), total phenolic and flavonoid compounds, antioxidant capacity, and microencapsulation stability. Also, the bioactive and sensory properties were investigated in a model beverage obtained by adding these saffron microcapsules to apple juice. The result of the study showed that adding the lowest number of saffron microcapsules to apple juice improved its bioactive compounds, antioxidant activity, color, and overall taste. This is the first study to use saffron microcapsules as a colorant, and the results showed that saffron microcapsules can be used as a colorant and fortifier in food formulation [13]. he aim of this study was to investigate the effect of different concentrations of crocin-balangu gum-sodium caseinate nanocomplex and postbiotics on the physicochemical (pH, physical stability), rheological, sensory, and microbial properties of dairy dessert during the storage period.

2-Materials and Methods

Materials used in the research included crocin as the diester gentiobiose crocin (Sigma-Aldrich, USA), emulsifier polyglycerol polyricinoleate (PGPR) (Palsgaard, Denmark), sodium caseinate, and plate count agar culture medium (Merck, Germany).

2-1- Preparation of balangu gum and sodium caseinate nanocomplex containing crocin nanoemulsion

The desired amount of balangu gum powder was added to distilled water, and the mixture was stirred by a magnetic stirrer (IKA-MAG HS 7, Germany) at 4000 rpm for 12 hours to absorb water and achieve a uniform texture. After heating in a water bath at 70°C for 10 minutes (to aid water absorption), it was kept in the refrigerator at 4°C for 12 hours to complete the water absorption process [8]. Sodium caseinate powder, after weighing, was added to distilled water and, after 30 minutes of mixing with a magnetic stirrer, was kept overnight at 4°C to ensure dissolution and complete hydration [9]. Sodium caseinate (0.5%) and balangu gum solution (0.5%) were mixed together, and after adjusting the pH to 3.5 to prepare the nanocomplex, the resulting mixture was passed through a high-pressure homogenizer.

To prepare the water-in-oil emulsion, polyglycerol polyricinoleate (PGPR) (HLB: 1.5) was used. A 10% w/w crocin solution along with different concentrations of emulsifier (0.5, 1, and 1.5%) were mixed on a magnetic stirrer. The aqueous phase containing the emulsifier was added dropwise to the oil phase. Then, the resulting emulsion was mixed at a constant speed of 1000 rpm for one hour. To prepare the double-layer emulsion, a 10% w/w water-in-oil microemulsion was added to the prepared aqueous solution containing the sodium caseinate/balangu gum complex (90% w/w). This mixture was mixed for 5 minutes at 1000 rpm using an Ultra-Turrax and then processed by a high-pressure homogenizer (2000 bar) [10].

2-2- Spray drying of balangu gum and sodium caseinate nanocomplex containing crocin nanoemulsion

A spray dryer (GEA, Denmark) was used to dry the emulsion liquid. The inlet air temperature was 170°C and the inlet feed temperature was 60°C, the outlet air temperature was 90°C, the air flow rate was 80 kg/h, and the water evaporation rate was 6 kg/h [8].

2-3- Preparation of pasteurized dairy desser

The preparation of Aloe vera dessert was done according to the method of Mahdizadeh et al. with slight modification. All required raw materials (pasteurized milk with 1.5% fat: 750 g, pasteurized cream with 30% fat: 50 g, sugar: 250 g, corn starch: 100 g) were weighed and after adding encapsulated crocin powder as well as pure crocin in ratios of 0.5, 1, and 1.5%, were transferred to a cooking stainless steel vessel. The product was cooked at 85°C for 30 minutes. Before the dessert samples cooled, the postbiotic solution was added at concentrations of 2.5, 5, and 10%. After that, the product was filled into polyethylene cups and after sealing, was transferred to a cold room at 4°C [11]. The amount of Aloe vera used in the dessert preparation was 10%, which was added to the mixture along with the main dessert ingredients [12]. The physicochemical properties of the dessert (pH, fat content, and dry matter content) were measured after production and also 15 and 45 days thereafter.

2-4- Measurement of rheological properties

To investigate the rheological properties of the samples, a rheometer equipped with concentric cylinder geometry (model CC27) was used. The ramp increase method of shear rate was used to measure shear stress and viscosity as a function of shear rate and to determine the type of flow behavior of the samples. For this purpose, over a time interval of 10 minutes, the shear rate was increased from 0.1 to 500 s^{-1}, and during this process, shear stress was measured every 10 seconds. This test was performed one day after sample preparation, and the samples were kept at 5°C until the test. Since the shear rate applied in many food processes such as pumping is stated as 100 s^{-1}, the viscosity obtained at a shear rate of 100 s^{-1} was reported as the apparent viscosity of the samples [8].

2-5- Total microbial count

The total microbial count in the pasteurized dairy dessert was performed using plate count agar culture medium based on standard No. 7110 (Pasteurized and packaged dessert - Microbiological characteristics) and standard No. 5272 (Microbiology of food and animal feed - Comprehensive method for counting total microorganisms at 30°C).

2-6- Sensory evaluation

Some sensory properties of the dessert containing encapsulated and pure crocin (including taste, texture and consistency, odor, mouthfeel, and overall acceptance) were evaluated within the framework of a 5-point hedonic test with 5 scores by 20 trained evaluators (aged 25-40 years). Scores (1, 2, 3, 4, and 5 corresponded to very unfavorable, unfavorable, average, favorable, and very favorable, respectively). The minimum score obtained for each sensory attribute was 1 and the maximum was 5. The prepared samples were stored in the refrigerator after packaging and coding (randomly using a combination of letters and numbers). The next day, the samples were taken out of the refrigerator (5°C) and given to the evaluators to assess the samples for sensory characteristics. Then, the average scores obtained for each of the sensory attributes were calculated, and finally, the significance of the difference between the samples was determined [11].

2-7- Statistical methods and variables

This experiment was conducted in a completely randomized design based on a factorial arrangement. Statistical analysis of the results was performed using SPSS 22 software, and means were compared using Duncan's test at a 95% confidence level.

3- Results and discussion

3-1- Release rate of crocin from encapsulated nanoemulsion in dairy dessert

The release rate of crocin from the encapsulated nanoemulsion in the dairy dessert is shown in Figure 1

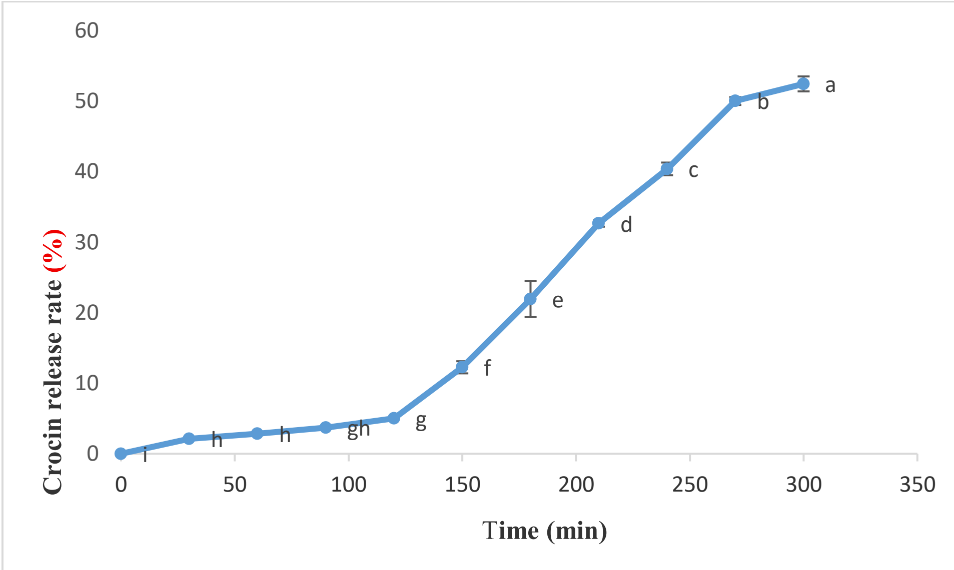

Figure 1-Crocin release rate from nanoemulsion powder in dairy dessert

According to the results in Figure 1, it can be concluded that with increasing time, the release rate of crocin in the dairy dessert also increases. Various factors influence the release of crocin, including sample storage temperature, method and conditions of storage and transportation, constituent compounds, amount and type of crocin encapsulation, the method of producing the nanocapsule, chemical factors and compounds, and the studied parameters of dairy desserts.

3-2- pH, fat content, and nonfat dry matter content of dairy dessert samples

The produced dairy dessert samples containing 2.5 to 10% postbiotics along with 0.5 to 1.5% free crocin and crocin encapsulated with sodium caseinate and balangu gum (0.5% each) (optimal sample) were examined and compared. The results of analysis by one-way ANOVA and Duncan's test for pH, fat, and dry matter of dairy desserts are shown in Figures 2, 3, and 4, respectively.

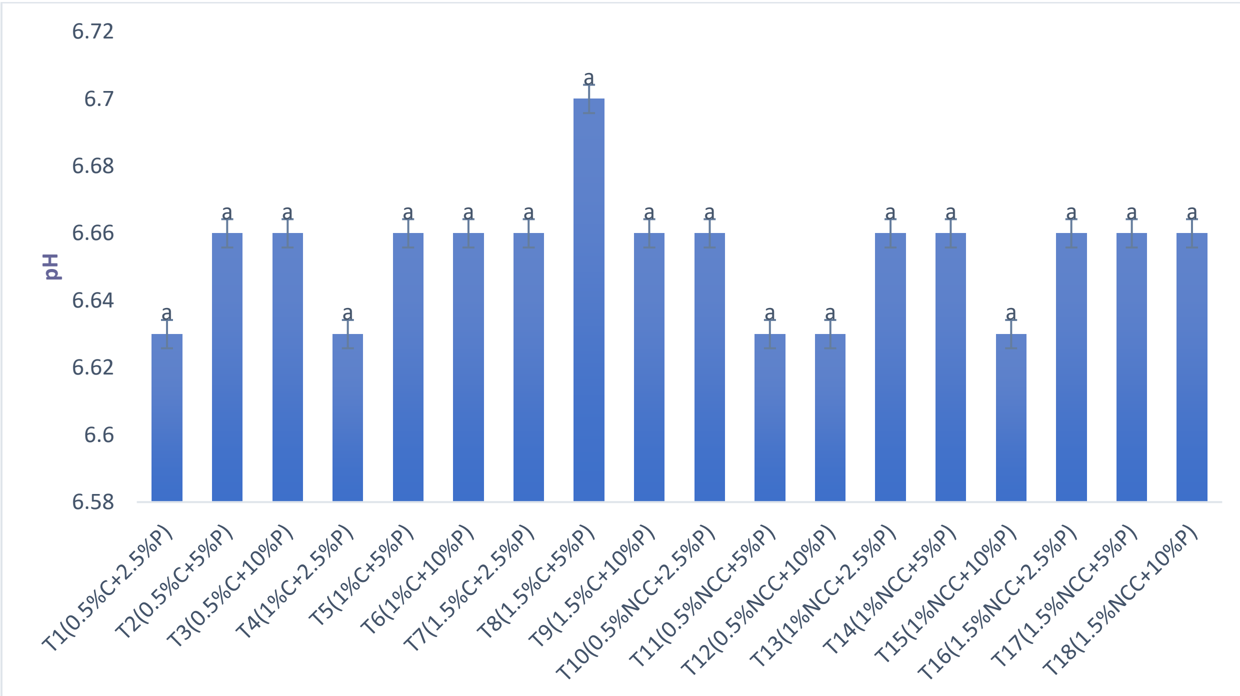

Figure 2- pH of dairy dessert samples

Numbers = mean of three replicates ± standard deviation, different lowercase letters indicate significant differences (P≤0.05)

C = crocin, NCC= encapsulated crocin, P = postbiotic

As shown in Figure 2, there is no statistically significant difference between the pH values of the dairy dessert samples (p>0.05). This means that the amount of crocin, the type of crocin (free or encapsulated), and the amount of postbiotic used in the formulation of dairy desserts do not affect the pH of the samples. The pH of the samples ranged from 6.63 to 6.70. According to Iranian National Standard No. 14681, the pH of dairy dessert samples should be between 6.3 and 6.7. All produced dairy dessert samples have pH within the standard range. Bayram et al. used encapsulated crocin in the production of apple juice. In their research, the results showed that the effect of the food colorant on the change in pH of the samples was not statistically significant. Their results are consistent with the results of the present study [13].

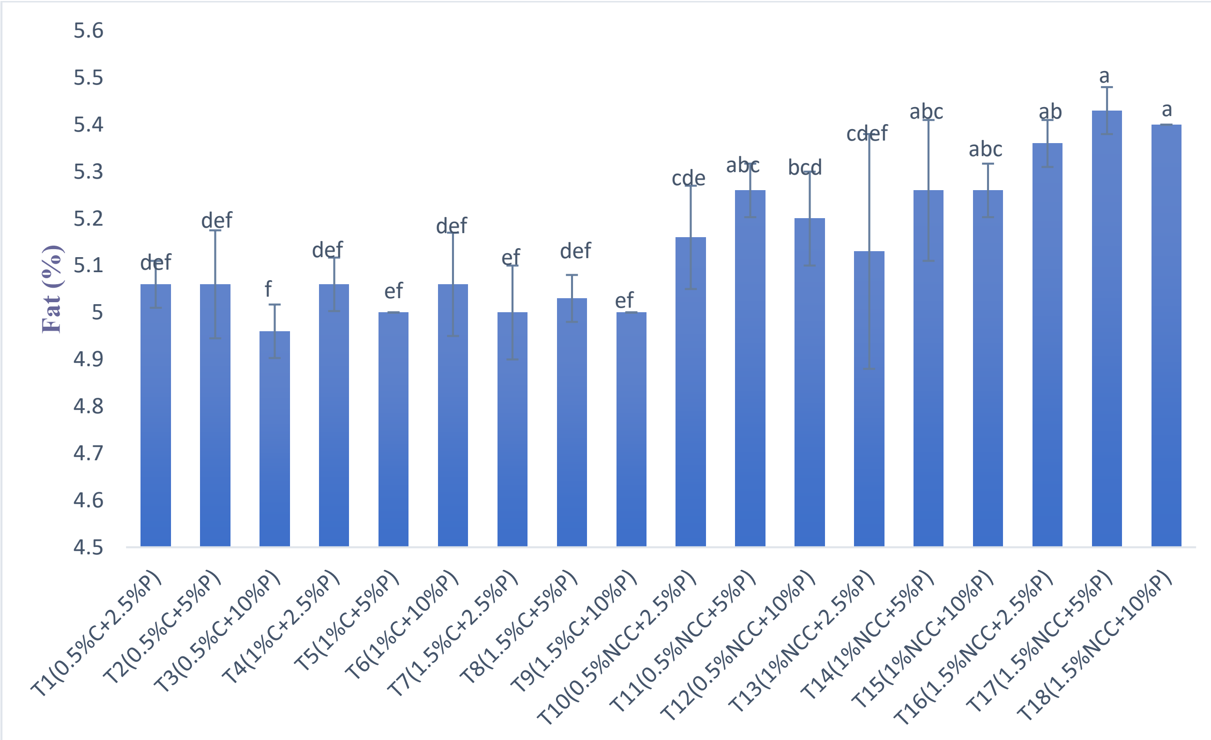

Figure 3- Fat content (%) of dairy dessert samples

C = crocin, NCC= encapsulated crocin, P = postbiotic

According to the results in Figure 3, there is a significant difference in fat content among some of the dairy dessert samples ($p<0.05$). The highest fat percentage is related to sample T17 (containing 1.5% encapsulated crocin and 5% postbiotic), which is equivalent to 5.43%, although there is no significant difference in fat content between this sample and samples T18 (containing 1.5% encapsulated crocin and 10% postbiotic), T16 (containing 1.5% encapsulated crocin and 2.5% postbiotic), T15 (containing 1% encapsulated crocin and 10% postbiotic), and T14 (containing 1% encapsulated crocin and 5% postbiotic) ($p>0.05$). The lowest fat content is related to sample T3 (containing 0.5% crocin and 10% postbiotic), which is equivalent to 4.96%, and there is no statistically significant difference in fat content between this sample and some other samples (samples in whose formulation free crocin was used) ($p>0.05$). What is clear from the results is that the amount of postbiotic does not have a statistically significant effect on the fat percentage of the samples; however, the type of crocin used in the formulation is effective, and in samples containing encapsulated crocin as a nanoemulsifier, the fat content is higher than in dairy dessert samples in whose formulation free crocin was used. On the other hand, in samples containing encapsulated crocin, with an increase in the amount of this nanoemulsifier, the fat content increases. The added nanoemulsion powder itself also contains fat, and the reason for the increase in fat content in encapsulated crocin samples is the presence of fat in them.

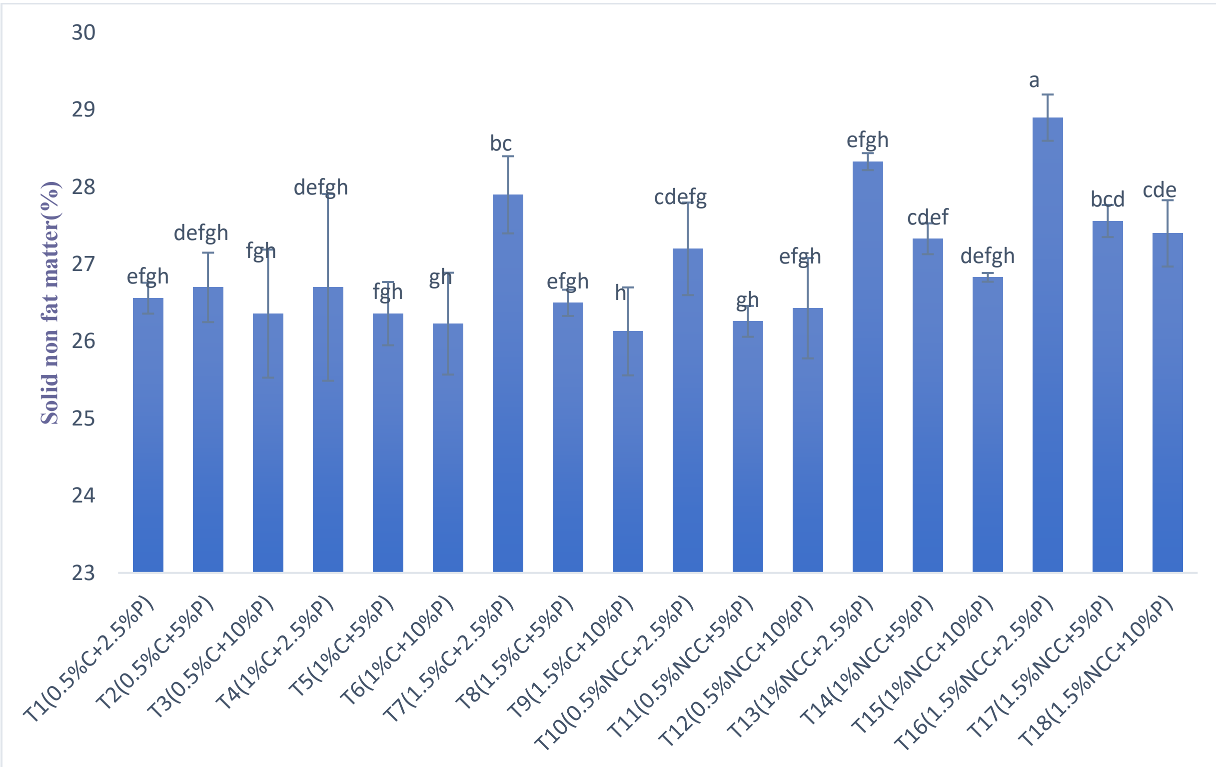

Figure 4- Nonfat solid matter (%) of dairy dessert samples

C = crocin, NCC= encapsulated crocin, P = postbiotic

According to the results in Figure 4, there is a significant difference in dry matter content among some of the dairy dessert samples ($p<0.05$). The highest dry matter percentage is related to sample T16 (containing 1.5% encapsulated crocin and 2.5% postbiotic), which is equivalent to 28.90%, although there is no significant difference in dry matter content between this sample and sample T13 (containing 1% encapsulated crocin and 2.5% postbiotic) ($p>0.05$). The lowest dry matter content is related to sample T9 (containing 1% crocin and 10% postbiotic), which is equivalent to 26.13%, and there is no statistically significant difference in dry matter content between this sample and some other samples (samples in whose formulation free crocin was used) ($p>0.05$). What is clear from the results is that the amount of postbiotic has a statistically sig nificant effect on the dry matter percentage in some samples, such as sample T16 compared to samples T17 and T18, where the amount of encapsulated crocin is the same but the amount of postbiotic is different, and with an increase in postbiotic, the dry matter content has decreased. In most samples with the same percentage of free crocin and encapsulated crocin but different amounts of postbiotic, this difference is also observed, and with an increase in postbiotic, the dry matter content decreases. In most samples with the same amount of postbiotic, with an increase in the amount of crocin, especially in samples in whose formulation encapsulated crocin was used, with an increase in the amount of crocin, the dry matter percentage increases, although in some samples this difference is not significant ($P>0.05$). However, the type of crocin used in the formulation is effective, and in samples containing encapsulated crocin (at 1 and 1.5%), as a nanoemulsifier, the dry matter content is higher than in dairy dessert samples in whose formulation free crocin (1 and 1.5%) was used. On the other hand, in samples containing encapsulated crocin, with an increase in the amount of this nanoemulsifier, the dry matter content increases. Nazari and Asili used encapsulated crocin in chocolate formulation. According to their results, there was a significant difference between chocolates containing double-layer emulsions in terms of moisture and water activity, and these factors increased with the addition of double-layer emulsions to chocolate [10]. Ngo et al. encapsulated roselle pigment (from the hibiscus plant) with maltodextrin and xanthan and used it in a famous Vietnamese dessert. According to their results, the pH of samples containing encapsulated pigment was lower than the control sample, but the difference was not statistically significant [14]. Yazdanpanah et al. used encapsulated red beet pigment in dairy dessert. According to these researchers' results, the dessert containing encapsulated pigments showed smaller pH changes compared to samples containing free pigment and the control sample [15].

3-3- Total microbial count in dairy dessert over time

The results of the comparison of mean total microbial counts of dairy desserts on the first, 15th, and 30th days of storage are shown in Figures 5, 6, and 7, respectively.

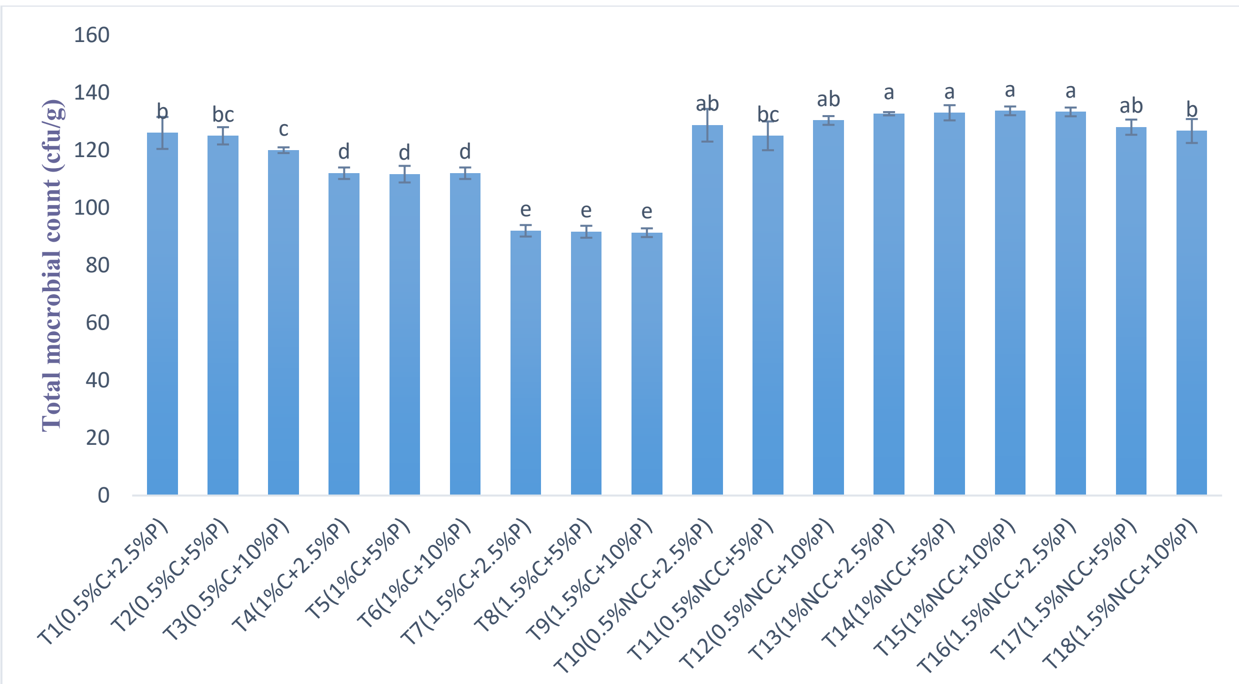

Figure 5 - Total microbial count of dairy dessert samples on the first day

C = crocin, NCC= encapsulated crocin, P = postbiotic

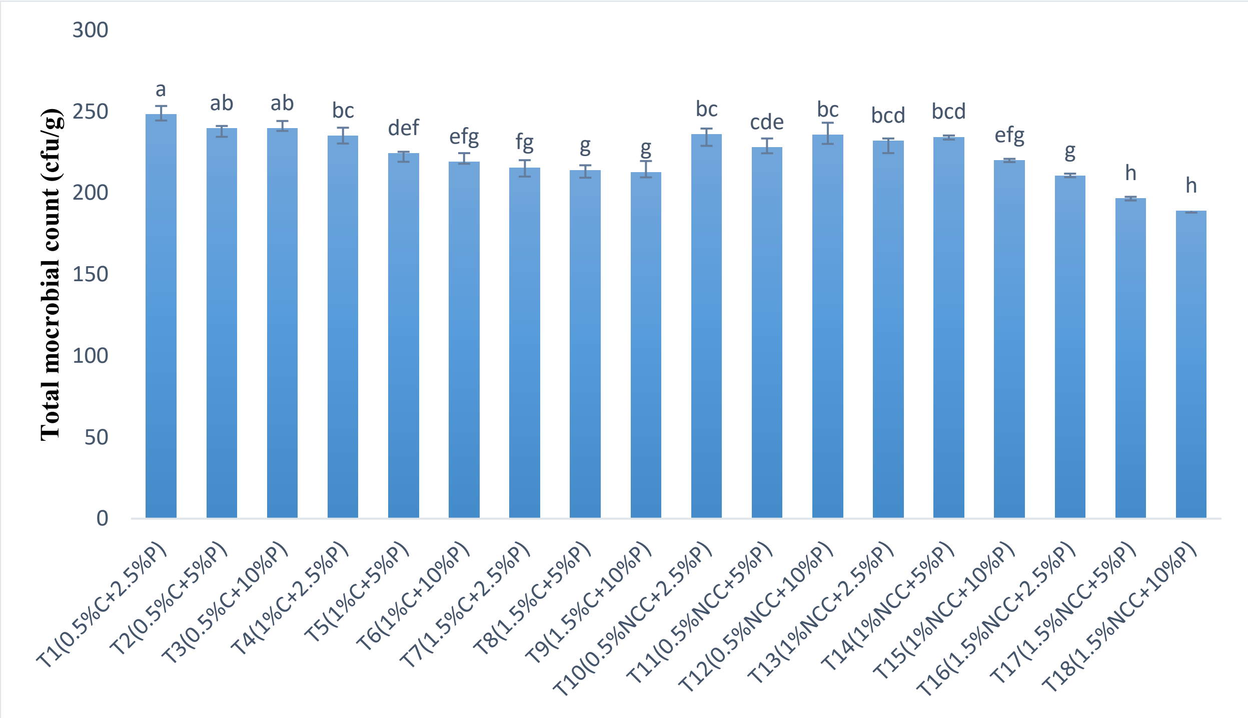

Figure 6 - Total microbial count of dairy dessert samples on the 15th day
C = crocin, NCC= encapsulated crocin, P = postbiotic

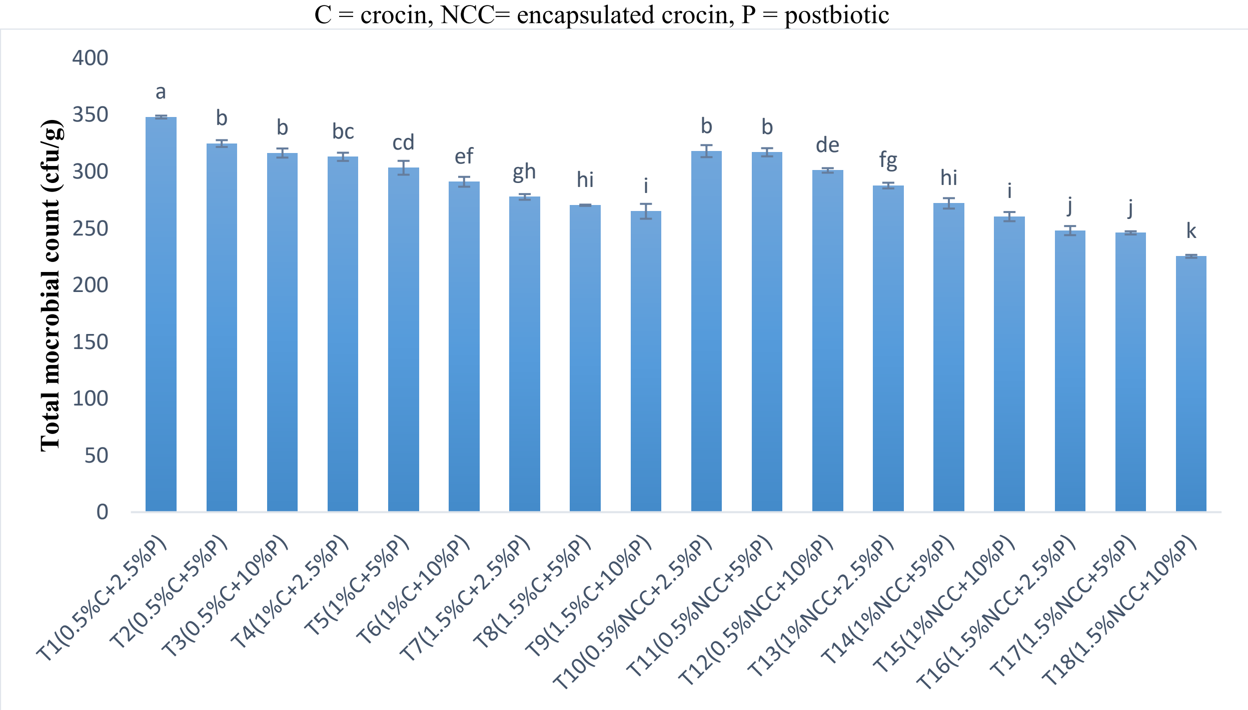

Figure 7 - Total microbial count of dairy dessert samples on the 30th day
C = crocin, NCC= encapsulated crocin, P = postbiotic

According to the figures related to the total microbial count in dairy desserts, what is clear is that during the examined time period, taken separately, there is a statistically significant difference in the total microbial count among some of the examined dairy desserts ($p<0.05$), while in some samples, this difference was not significant. On the other hand, on the first day of production, at the same amounts of crocin and encapsulated crocin, samples containing encapsulated crocin had a higher microbial count than samples containing crocin. In samples containing free crocin, with an increase in the amount of crocin, the total microbial count decreased, and in samples with the same amount of free crocin, increasing postbiotics had almost no significant effect on the total microbial count. In samples containing encapsulated crocin, in almost most samples, changing the amount of postbiotic and encapsulated crocin did not create a significant difference in the total microbial count. On the first day of storage, the lowest microbial count was related to sample T9 (containing 1.5% free crocin and 10% postbiotic), which, however, did not have a significant difference with samples T8 and T7. The highest total microbial count on the first day of production was related to sample T15 (containing 1% encapsulated crocin and 10% postbiotic).

On the 15th day of storage, there is a statistically significant difference between the mean total microbial counts in most of the dairy dessert samples ($p<0.05$). In samples containing free crocin, there is no significant difference between samples containing 0.5% free crocin with different percentages of postbiotic (2.5, 5, and 10%) ($p>0.05$). Also, in samples containing free crocin, there is no significant difference between samples containing 1.5% free crocin with different percentages of postbiotic (2.5, 5, and 10%) ($p>0.05$); similarly, in samples containing encapsulated crocin, between samples containing 0.5% encapsulated crocin with different percentages of postbiotic (2.5, 5, and 10%), there is no significant difference ($p>0.05$). What is clear from Figure 6 is that the amount of crocin and the type of crocin (free and encapsulated) affect the total microbial count, but the amount of postbiotics does not have a significant effect on the total microbial count in most samples. With an increase in the amount of crocin and encapsulated crocin in the examined dessert samples, the total microbial count decreased. At the same amounts of crocin and encapsulated crocin, encapsulated crocin has a greater effect, such that on the 15th day of storage, the lowest total microbial count is related to the sample containing 1.5% encapsulated crocin and 10% postbiotic, although there is no statistically significant difference in the microbial count between this sample and the sample containing 1.5% encapsulated crocin and 5% postbiotic. The highest total count is related to the dairy dessert sample containing 0.5% free crocin. On the 30th day of storage, there is a statistically significant difference between the mean total microbial counts in most of the dairy dessert samples ($p<0.05$). What is clear from Figure 7 is that with an increase in the amount of crocin and encapsulated crocin and an increase in postbiotic, the total microbial count decreases, and samples with more crocin and postbiotic have a lower total microbial count. On the 30th day of storage, the lowest total microbial count is related to the sample containing 1.5% encapsulated crocin and 10% postbiotic, although there is no statistically significant difference in the microbial count between this sample and the sample containing 1.5% encapsulated crocin and 5% postbiotic. The highest total count is related to the dairy dessert sample containing 0.5% free crocin and 2.5% postbiotic.

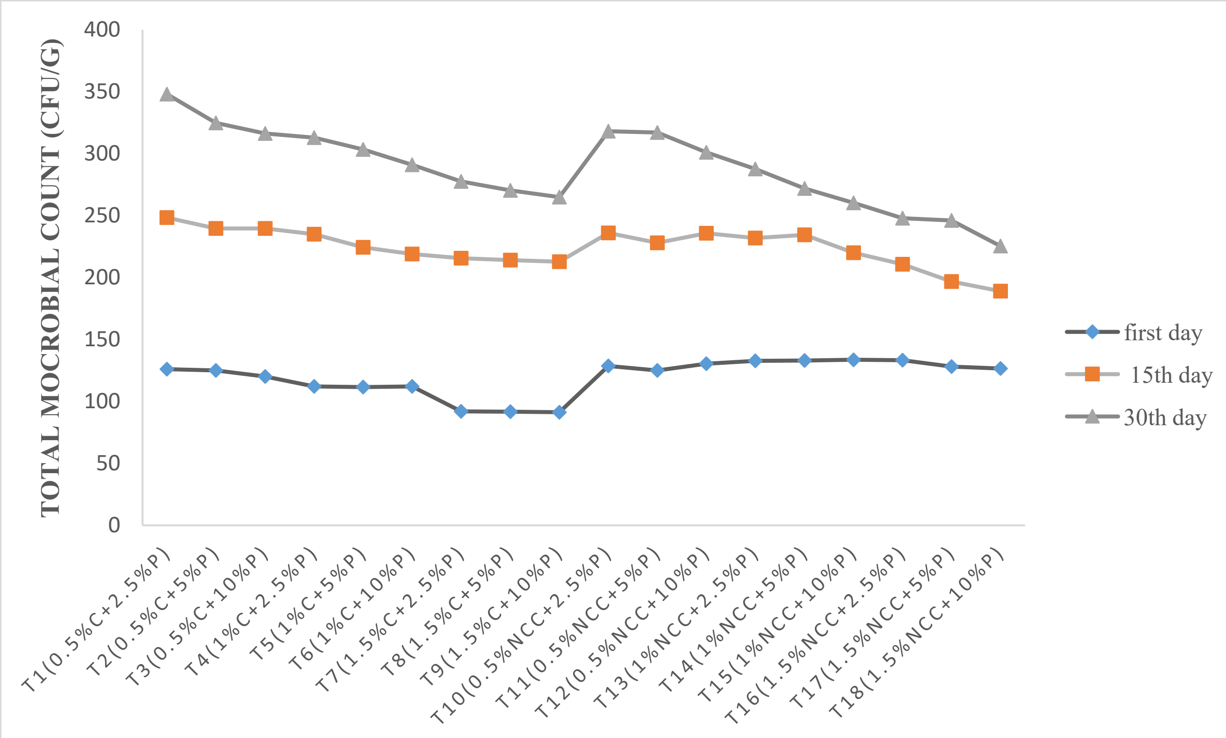

Figure 8 - Effect of storage period on total microbial count in dairy dessert samples
C = crocin, NCC= encapsulated crocin, P = postbiotic

Figure 8 shows the total microbial count in the three examined time periods (first day, 15th day, and 30th day). According to the graph, with increasing storage time, the total microbial count increases, which is quite obvious.

Crocin has antimicrobial properties, so with an increase in its amount in the dairy dessert formulation, the total microbial count decreases. The antimicrobial property of crocin is high against spoilage bacteria, molds, and yeasts, which is why with an increase in the concentration of this bioactive compound, the antimicrobial property increases. On days 15 and 30, nanoencapsulated crocin had a more effective role in reducing the microbial load, which is due to the fact that the wall formed by sodium caseinate and balangu gum better preserved its bioactive properties, and on the other hand, balangu gum itself also has antimicrobial properties. Balangu is a seed that contains flavonoids, glycosides, terpenoids, tannins, etc., and its antimicrobial properties have been proven [16]. Cerda-Bernad et al. used crocin encapsulated with alginate in yogurt production. According to these researchers' results, encapsulated crocin had a significant effect on reducing mold and yeast during yogurt storage [17]. Yousefi et al. investigated the effects of nanoliposomes containing crocin and nisin in milk samples as a food model. In this research, three formulations were prepared and compared: (1) milk samples containing nisin and free crocin, (2) samples containing nanoliposomes containing nisin and crocin, and (3) nanoliposomes containing nisin and crocin coated with chitosan. According to these researchers' results, the lowest bacterial count was observed in samples with chitosan-coated nanoliposomes [18]. Several reasons have been given for the more effective effect of encapsulated bioactive compounds compared to free bioactive compounds. The first mechanism is attributed to passive cellular uptake, meaning that nano-sized drug delivery systems, due to their subcellular size, can easily pass antimicrobial substances through cell walls and membranes via the passive cellular uptake mechanism, thus reducing mass transfer resistance [19]. Also, it has been stated that the encapsulation process in nanoparticles increases the biological activities of compounds by increasing their concentration and bioavailability due to the increased surface-to-volume ratio by reducing particle size to the nanoscale [20]. Yazdanpanah et al. used encapsulated red beet pigment in dairy dessert; according to these researchers' results, the dessert containing encapsulated pigments had a lower microbial load, mold, and yeast compared to samples containing free pigment and the control sample [15]. The results of these researchers are consistent with the results of the present study.

3-4- Apparent viscosity of dairy dessert after 14 days of storage

The effect of the studied treatments on the apparent viscosity of dessert samples is shown in Figure 9.

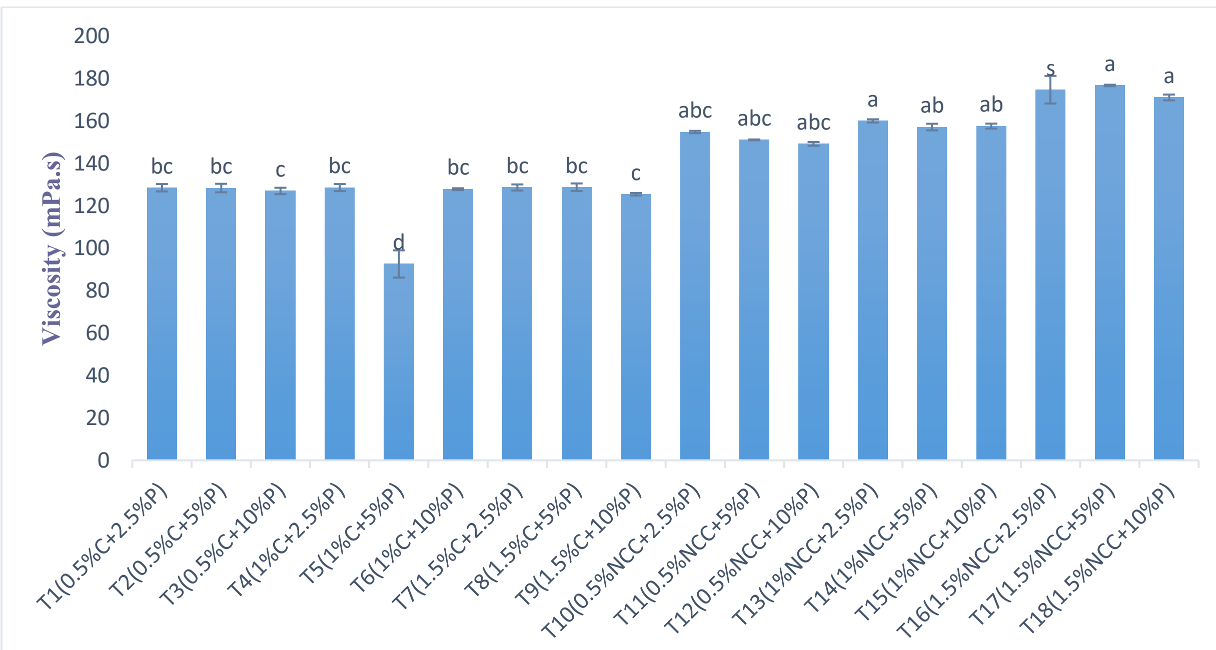

Figure 9 - Apparent viscosity of dairy dessert samples
C = crocin, NCC= encapsulated crocin, P = postbiotic

According to Figure 9, it is observed that among samples containing free crocin, with the same amount of free crocin, as the amount of postbiotic increases, there is no significant difference in the apparent viscosity of the samples, except for the sample containing 1% free crocin and 5% postbiotic (T5), which has a significant difference with samples T4 and T6. In samples containing encapsulated crocin, with the same amount of encapsulated crocin, as the amount of postbiotic increases, there is no significant difference in the apparent viscosity of the samples ($p>0.05$). This means that the amount of postbiotic does not have a significant effect on apparent viscosity, but the amount and type of crocin (free and encapsulated) have a significant effect on apparent viscosity in some samples. In dairy dessert samples, with an increase in the amount of free crocin, almost no significant difference was observed in the viscosity of the samples, except for sample T5, which has a lower viscosity than other samples. In dairy dessert samples, with an increase in the amount of encapsulated crocin, an almost significant difference was observed in the viscosity of the samples, and with an increase in the amount of encapsulated crocin, the apparent viscosity increased. In encapsulated crocin, sodium caseinate and balangu gum were used, and these compounds increase viscosity. Balangu gum has polysaccharide and hydrocolloid properties, which themselves cause higher water absorption and increased viscosity. With an increase in the amount of encapsulated crocin, the amount of gum and sodium caseinate also increases, leading to increased viscosity. Among the dairy dessert samples, the sample containing 1.5% encapsulated crocin and 5% postbiotic has the highest apparent viscosity (176.77 mPa·s); however, the viscosity of this sample does not differ significantly from other samples containing encapsulated crocin. The rheological properties and final quality of the dessert are influenced by the particle size distribution and composition of the dessert, which play an important role in the sensory perception of this product. Coarse particles are effective in creating mouthfeel due to their sandy nature, but fine particles are more important due to their influence on flow properties. Reducing particle size increases viscosity and yield stress. Particle size distribution is important because it can be optimized to achieve desired rheological prop erties without any overall change in dessert formulation [10]. Yousefi et al. investigated the effects of nanoliposomes containing crocin and nisin in milk samples as a food model. According to these researchers' results, encapsulated nanoliposomes increased the product viscosity more than free crocin [18].

3-5- Sensory properties of dairy dessert samples

3-5-1- Taste

The effect of the studied treatments on the taste scores of dessert samples is shown in Figure 10.

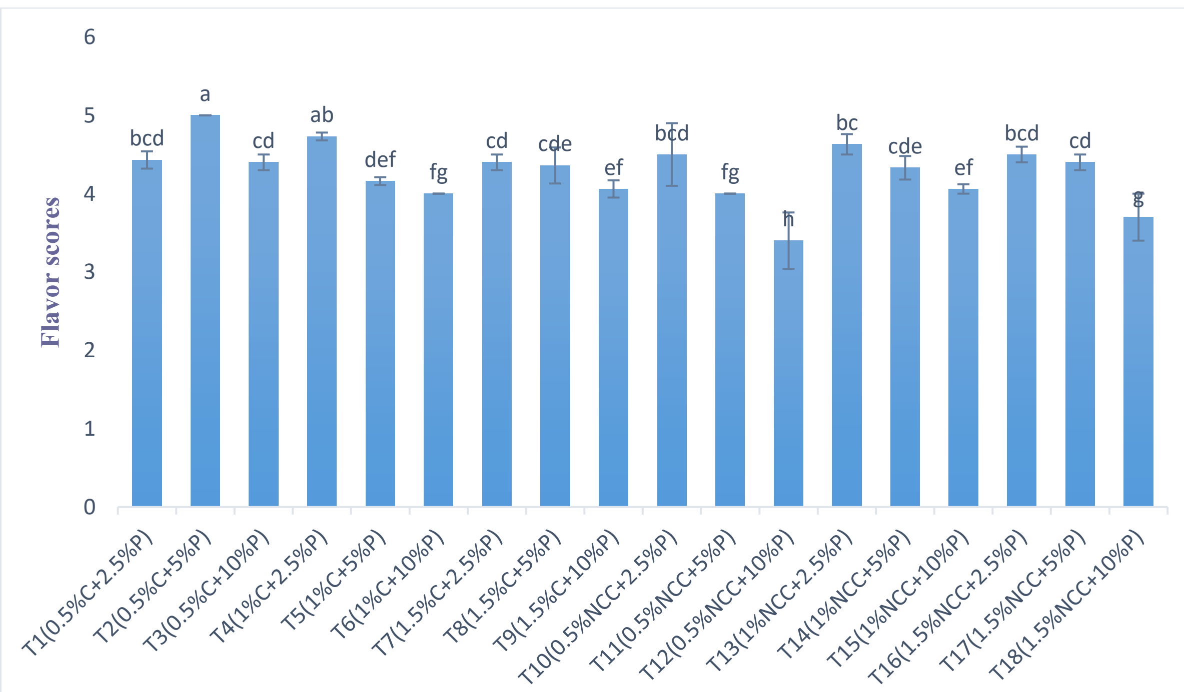

Figure 10 - Means flavor scores of dairy dessert samples

C = crocin, NCC= encapsulated crocin, P = postbiotic

According to the sensory evaluation results for the taste of dairy dessert samples, there is a statistically significant difference between the mean taste scores in some samples ($p<0.05$). In the dairy dessert samples, except for three samples containing 0.5% free crocin, in the rest of the samples with a constant amount of crocin, the mean scores decreased with increasing postbiotic amount. With a constant amount of postbiotic in the samples, as the crocin amount increased up to 1%, the scores increased, such that they are higher than samples containing 0.5% and 1.5% crocin with a constant amount of postbiotic. The lowest taste score in the dairy dessert samples is related to sample T12 (sample containing 0.5% encapsulated crocin and 10% postbiotic), and the highest score is related to sample T2 (containing 0.5% free crocin and 5% postbiotic).

3-5-2- Odor

The effect of the studied treatments on the odor scores of dessert samples is shown in Figure 11.

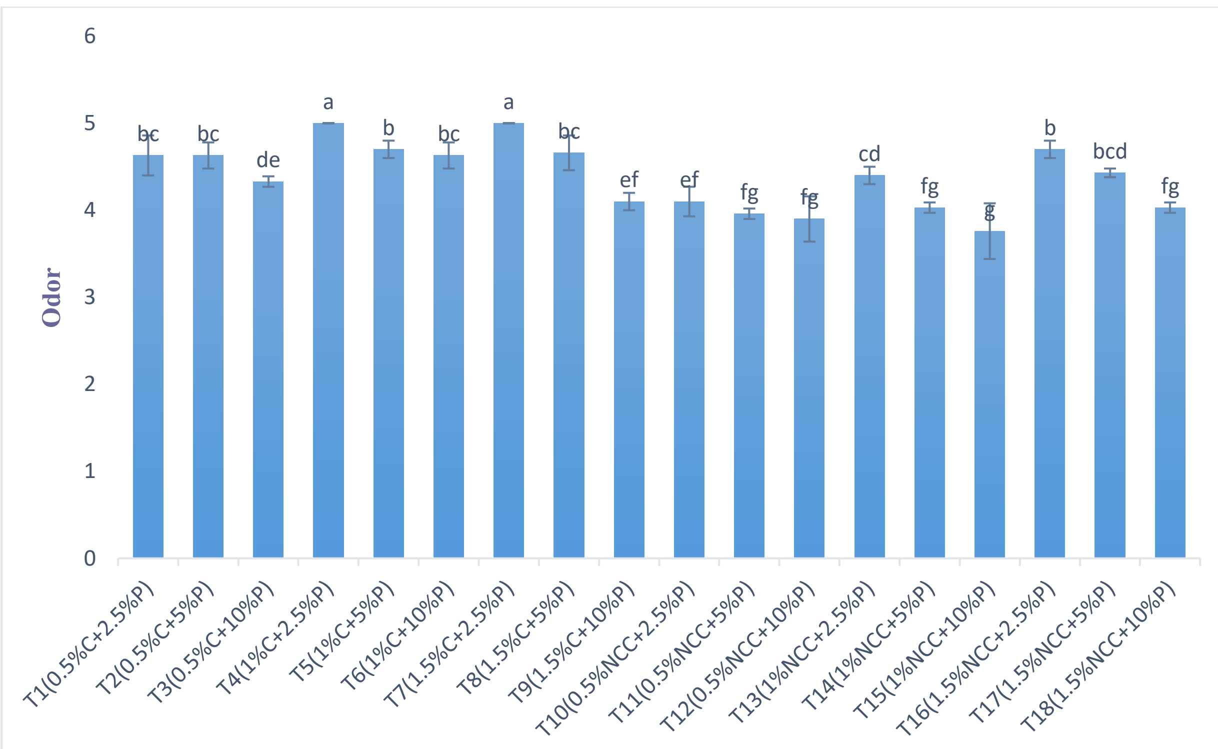

Figure 11 - Means odor scores of dairy dessert samples
C = crocin, NCC= encapsulated crocin, P = postbiotic

According to the sensory evaluation results for the odor of dairy dessert samples, there is a significant difference between the mean odor scores in some samples ($p<0.05$). In the dairy dessert samples, with a constant amount of crocin, the mean odor scores decreased with increasing postbiotic amount. With a constant amount of postbiotic, samples containing 0.5% crocin obtained higher scores, and the odor scores decreased in samples with increasing free crocin, while in samples containing encapsulated crocin, the scores increased with increasing encapsulated crocin. The lowest score among the dairy dessert samples is related to sample T15 (sample containing 1% encapsulated crocin and 10% postbiotic), and the highest score is related to sample T4 (containing 1% free crocin and 2.5% postbiotic) and T7 (containing 1.5% free crocin and 2.5% postbiotic). Since crocin is the pigment of saffron and has a desirable color, odor, and taste, and free crocin exhibits these features better than encapsulated crocin, samples containing free crocin obtained good scores, although the difference in scores was not significant in most samples.

3-5-3- Color

The effect of the studied treatments on the color scores of dessert samples is shown in Figure 12.

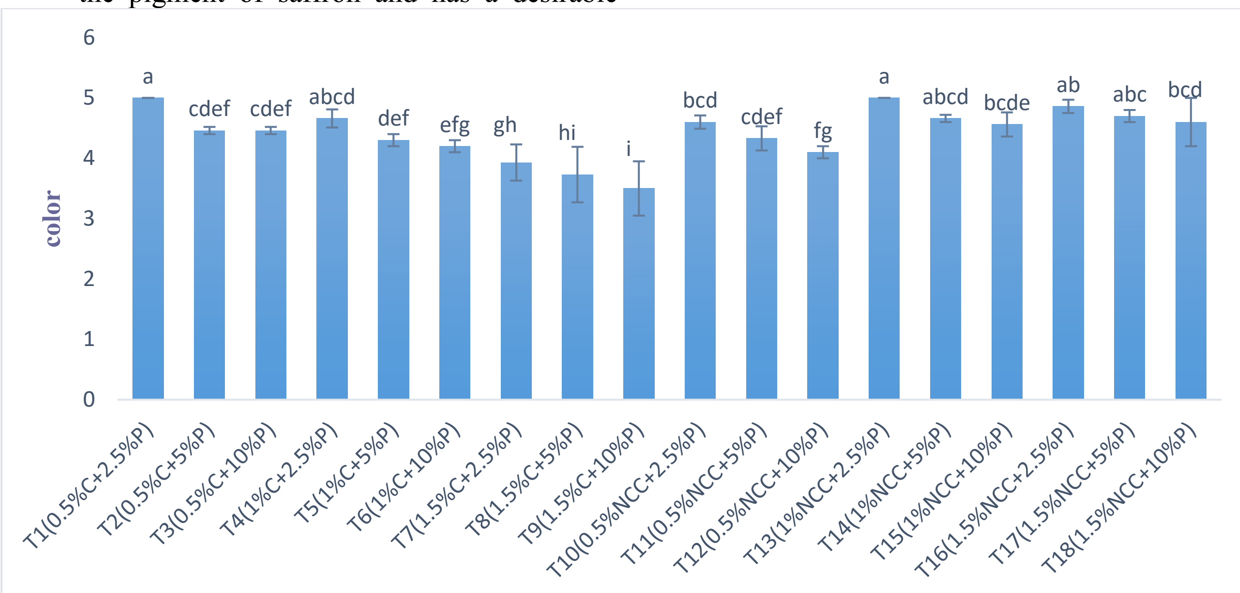

Figure 12 - Means color scores of dairy dessert samples
C = crocin, NCC= encapsulated crocin, P = postbiotic

According to the sensory evaluation results for the color of dairy dessert samples, there is a statistically significant difference between the mean color scores in some samples ($p<0.05$). In the dairy dessert samples, with a constant amount of crocin, the mean scores decreased with increasing postbiotic amount. With a constant amount of postbiotic, samples containing 0.5% free crocin obtained higher scores, and the color scores decreased in samples with increasing crocin (free and encapsulated). The lowest color score among the dairy dessert samples is related to sample T9 (sample containing 1.5% free crocin and 10% postbiotic), and the highest score is related to sample T1 (containing 0.5% free crocin and 2.5% postbiotic) and T13 (containing 1% encapsulated crocin and 2.5% postbiotic). In general, the scores of samples containing encapsulated crocin are higher than those containing free crocin, and this is due to the lower release of the crocin pigment from encapsulated samples compared to free crocin samples, indicating that encapsulation reduces the likelihood of release in the dairy dessert and increases the scores.

3-5-4- Texture

The effect of the studied treatments on the texture scores of dessert samples is shown in Figure 13.

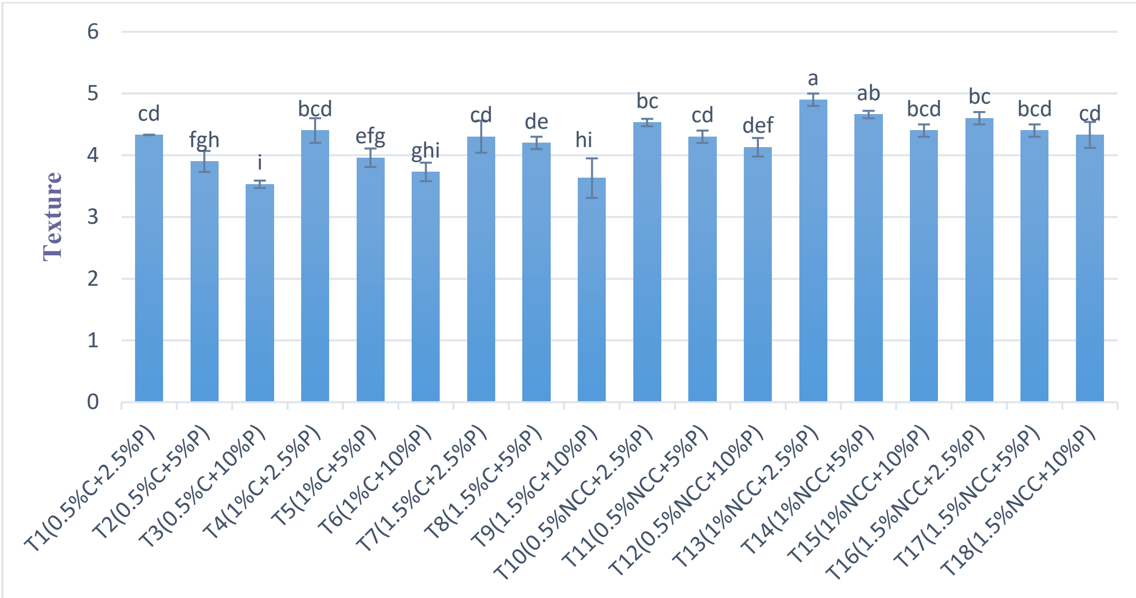

Figure 13 - Means texture scores of dairy dessert samples
C = crocin, NCC= encapsulated crocin, P = postbiotic

According to the sensory evaluation results for the texture of dairy dessert samples, there is a statistically significant difference between the mean texture scores in some samples ($p<0.05$). In the dairy dessert samples, with a constant amount of crocin, the mean scores decreased with increasing postbiotic amount. With a constant amount of postbiotic, samples containing 0.5% crocin obtained higher scores, and the texture scores decreased in samples with increasing crocin. The lowest texture score among the dairy dessert samples is related to sample T3 (sample containing 0.5% free crocin and 10% postbiotic), and the highest score is related to sample T1 (containing 0.5% free crocin and 2.5% postbiotic) and T13 (containing 1% encapsulated crocin and 2.5% postbiotic).

3-5-5- Overall acceptance

The effect of the studied treatments on the overall acceptance scores of dessert samples is shown in Figure 14.

Figure 14 - Means overall acceptance scores of dairy dessert samples

C = crocin, NCC= encapsulated crocin, P = postbiotic

According to the sensory evaluation results for the overall acceptance of dairy dessert samples, there is a statistically significant difference between the mean overall acceptance scores in some samples ($p<0.05$). In the dairy dessert samples, with a constant amount of crocin, the mean scores decreased with increasing postbiotic amount. Samples containing encapsulated crocin obtained higher scores compared to samples containing free crocin. The lowest overall acceptance score among the dairy dessert samples is related to sample T9 (sample containing 1.5% free crocin and 10% postbiotic), and the highest score is related to sample T13 (containing 1% encapsulated crocin and 2.5% postbiotic).

Ganji et al. used gelatin to encapsulate crocin and used encapsulated crocin and free crocin in crystallized candy (Nabat). According to these researchers' results, there was a significant difference in the sensory properties of crystallized candy samples containing encapsulated crocin and samples containing pure crocin. Accordingly, the panelists recorded higher scores for the color and taste of crystallized candy containing encapsulated crocin. However, the transparency of crystallized candy containing encapsulated crocin was significantly lower compared to other samples. It is noteworthy that all sensory properties of the samples were acceptable compared to the control sample (without crocin) [21]. Nazari and Asili used encapsulated crocin in milk chocolate formulation, and according to their results, the enriched treatment had the highest taste score. There was no significant difference between treatments in terms of melting in the mouth. In terms of color intensity, the highest score was given to the treatment enriched with nanoencapsulated crocin [10]. In the research by Bayram et al., different amounts of saffron microcapsule colors were used in coloring apple juice, and it was found that the effect of the food colorant on the color value of all samples compared to the control group was statistically significant in the sensory analysis of the color parameter. Samples containing higher amounts of saffron microcapsules were most preferred in terms of odor. In this study by these researchers, where different amounts of saffron microcapsule colors were used in colored apple juices, it was found that the effect of the food colorant on the odor value of the samples was not statistically significant. Samples containing higher amounts of microcapsules were the most popular sample in terms of taste, and it was found that the effect of the food colorant on the taste value of all samples compared to the control group was not statistically significant. It is estimated that with an increasing amount of dissolved saffron microcapsule color in apple juice, more aroma and flavor are released. When all samples were compared with the control group in terms of aroma intensity, it was found that the effect of the food colorant was not statistically significant [13].

4-Conclusion

In this research, the optimal produced nanoemulsion (encapsulated crocin) under optimal drying conditions, as well as free crocin at 0.5, 1, and 1.5% along with postbiotics at 2.5, 5, and 10%, were used in the dairy dessert formulation. In general, the results showed that the effect of encapsulated crocin on increasing fat, dry matter, and viscosity was higher than that of free crocin. According to the results, encapsulated crocin had a greater effect on reducing microbial load. The results related to sensory evaluations also showed that the sample containing 1% encapsulated crocin and 2.5% postbiotic obtained a higher overall acceptance score.

Data Availability

The data used to support the finding of this study are available from the corresponding author upon request.

Conflict Of Interest

The authors have no conflicts interest to report.

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مقاله علمی_پژوهشی

بررسی تولید دسر لبنی کم چرب حاوی پست بیوتیک ها، آلوئه ورا و کروسین درون پوشانی شده با کمپلکس صمغ بالنگو و پروتئین کازئینات سدیم

رقیه عزتی[۱]، لیلا روزبه نصیرایی[۱]، سارا جعفریان[۱]، مسعود دزیانی[۲]، فاطمه شهدادی[۳]

۱-گروه صنایع غذایی، واحد نور، دانشگاه آزاد اسلامی، نور، ایران

۲- گروه صنایع غذایی، واحد گرگان، دانشگاه آزاد اسلامی، گرگان، ایران

۳-گروه صنایع غذایی، دانشکده کشاورزی، دانشگاه جیرفت، جیرفت، ایران

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چکیده

دسر لبنی از محصولات مورد پسند گروه زیادی از افراد جامعه است. جهت بهبود رنگ و بالا بردن ارزش تغذیه‌ای این محصول می‌توان از رنگدانه‌های طبیعی استفاده نمود. لذا هدف از این تحقیق تولید دسر لبنی کم چرب فراسودمند حاوی پست بیوتیک ها، آلوئه ورا و کروسین درون پوشانی شده با کمپلکس صمغ بالنگو و پروتئین کازئینات سدیم می باشد. در پژوهش حاصل از نانوامولسیون حاوی کروسین (درون پوشانی شده) در شرایط بهینه خشک کردن و همچنین کروسین آزاد به میزان ۰/۵، ۱ و ۱/۵ درصد همراه با پست بیوتیک به میزان ۲/۵، ۵ و ۱۰ درصد در فرمولاسیون دسرلبنی حاوی آلوئه ورا استفاده شد و تعداد ۱۸ نمونه تولید گردید و ویژگی‌هایی نظیر pH میزان چربی، میزان ماده خشک، ویسکوزیته ظاهری، شمارش میکروبی و ویژگی‌های حسی در طول دوره نگهداری مورد بررسی قرار گرفت. طبق نتایج ، میزان پست بیوتیک و نانوامولسیون بر روی pH تاثیر گذار نبود ($p>0.05$). بالاترین میزان چربی و ویسکوزیته مربوط به نمونه حاوی ۱/۵ درصد کروسین درون پوشانی شده و ۵ درصد پست بیوتیک (۵/۳ درصد و ۱۶۵ میلی پاسکال.ثانیه) و بیشترین میزان ماده خشک نیز مربوط به نمونه حاوی ۱/۵ درصد کروسین درون پوشانی شده و ۲/۵ درصد پست بیوتیک (۲۸/۵ درصد) بود و به طور کلی تاثیر کروسین درون پوشانی شده در افزایش چربی، ماده خشک و ویسکوزیته از کروسین آزاد بیشتر بود. نتایج میکروبی نیز نشان داد کروسین درون پوشانی شده تاثیر بیشتری در کاهش بارمیکروبی دارد. نتایج مربوط به ارزیابی‌های حسی نشان داد نمونه حاوی ۱ درصد کروسین درون پوشانی شده و ۲/۵ درصد پست بیوتیک، امتیاز پذیرش کلی بالاتری (۵) کسب نمودند.