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THE IMPACT OF STORAGE ON THE SENSORY, VISCOSITY AND CHEMICAL CHARACTERISTICS OF YOGURT FORTIFIED WITH OAT β–GLUCAN

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Abstract. *The feasibility of yogurt fortification with 0.3% oat β-glucan was examined. The results showed that 0.3% oat β-glucan yogurt has a water-holding capacity. The acidity value and pH reached their maximum values at 7 d of storage, and no significant changes were observed after 7 d. All pH values ranged from 4.18 to 4.28, which are within the normal ranges for set-type yogurts. Interestingly, the viscosity values increased throughout storage. Significant differences were noted between the control yogurt and 0.3% oat β-glucan yogurt. The experimental sample had a higher viscosity than the control yogurt, and the highest values were 58560 ± 2120 cp at 21 d for 0.3% oat β-glucan yogurt. The viability of probiotic bacteria in yogurts was checked. During the whole storage period, the content of probiotics decreased, which was only 0.63 ± 0.05 ×107 CFU/mL at 21 d. However, 0.3% oat β-glucan yogurt contained significantly more living probiotic bacteria compared to the control one, throughout the whole cold storage period. The viability of probiotic bacteria of 0.3% oat β-glucan yogurt at 14 d (3.18 ± 0.2 ×107 CFU/mL) was only slightly lower than that of control yogurt at 1 d (3.45 ± 0.3 ×107 CFU/mL). This fully demonstrates that the addition of 0.3% oat β-glucan has a protective effect on probiotics in yogurt, which will be beneficial for human health. The textural characteristics of yogurt were affected by the addition of 0.3% oat β-glucan, leading to decreased adhesiveness, but enhanced hardness and gumminess, throughout storage. All yogurts had average sensory scores of above 80, indicating a preference both for the control yogurt and 0.3% oat β-glucan yogurt throughout storage. The sensory results indicated that 0.3% oat β-glucan yogurt had the highest acceptability value of 86.49 at 21 d of storage, had a positive effect on the acceptability of the yogurt, independently of the storage time. Overall, yogurt containing 0.3% oat β-glucan could be an innovative healthy dairy product.*

Keywords: *yogurt, oat β-glucan, sensory, viscosity, chemical characteristics*

Introduction.

The demand for healthy foods has caused the development of products containing functional components. In the dairy industry, prebiotic substances or probiotic bacteria have sparked interest due to scientific evidence related to their positive health benefits (Chen et al., 2019).

Dietary fibers, usually polysaccharides, can be insoluble or soluble in water. Soluble fibers are usually found in fruits, vegetables, oat bran, and barley, etc. Oat β-glucan (OG), a soluble dietary fiber from oat, has received tremendous attention during the previous decades. It is a non-starchy polysaccharide that comprises mainly glucose molecules linked by (1–3), (1–4) mixed linkage with glycosidic bonds (Xu et al., 2021). More importantly, it has diverse and great effects on the maintenance and improvement of human health. For example, consumption of OG can help in reducing the occurrence of some chronic diseases such as high blood pressure, insulin responses, obesity, and colon cancer (Sarantis et al., 2021). In addition, it can modify the rheological and mouthfeel attributes, and physical stability of beverages, and be used as a prebiotic in yogurt formulations (Rosburg et al., 2010). Nowadays, consumption of OG is encouraged and it is added to various food products as a functional ingredient.

Analysis of recent researches and publications.

Yogurt, a traditional fermented dairy product containing probiotics and prebiotics, has gained widespread consumer acceptance for being considered as a healthy product (Jørgensen et al., 2019; García-Burgos et al., 2020). It has shown a substantial consumption increase in recent years due to its nutritional and health interest. During the fermentation action, some toxic or antinutritional factors, such as lactose and galactose, can be removed from fermented milk, thus preventing lactose intolerance and accumulation of galactose (Shiby & Mishra, 2013). In this sense, yogurt can be used as an excellent matrix for developing innovative health-promoting products and functional foods.

The addition of soluble fibers can change the structural-mechanical properties (Samilyk et al., 2020) and functional characteristics of fermented dairy products. For example, used hydrolyzed guar gum can be used to enhance the functional and sensory properties of yogurt (Mudgil et al., 2016). In recent years, there is growing interest to launch health-promoting foodstuffs with OG.

Because OG is a kind of dietary fiber, it can be used as a prebiotic of probiotics, and it has a positive influence on the physicochemical properties and vitality of probiotics in yogurt. This feature is conducive to OG as a functional component of yogurt (Ibrahim & Selezneva, 2019; Ibrahim et al., 2020).

From the analysis data of literature sources, we know that OG has the potential as a functional additive for yogurt; however, the texture analysis and chemical characteristics of the storage period after adding OG to yogurt still need to be more systematically studied.

As our previous report, the addition of 0.3% OG decreased the fermentation time of set-type yogurt, making the highest score of sensory evaluation (Qu et al., 2021). As a functional food ingredient, 0.3% OG is important in enhancing the nutraceutical quality and physical characteristics of yogurt. Moreover, 0.3% OG shows its effect on starter culture growth. However, the impact of 0.3% OG on the quality of yogurt, such as sensory evaluation and physical characteristics, during storage, has not been evaluated. So, in this work, the quality characteristics of set-type yogurt, i.e., control yogurt and 0.3% OG yogurt, were studied. The water-holding capacity (WHC), acidity value, pH, viscosity, textural parameters, viability of probiotic bacteria, and sensory properties, during 21 d of storage, were evaluated and compared.

The aim and objectives of the study. The aim of the study is to analyze the effect of the feasibility of set-type yogurt fortification with 0.3% OG.

To achieve the aim of the study, it was necessary to solve the following problems:

– to analyze the effects of yogurt with or without 0.3% OG on sensory during storage;
– to analyze the impact of yogurt with or without 0.3% OG on viscosity and chemical properties during storage;
– to investigate the effect on probiotics in yogurt with or without 0.3% OG during storage.

Materials and methods.

Pure milk was purchased from Yili Industrial Group Co. Ltd (Neimenggu, China). Oat β-glucan (95% purity) was provided by Zhongkang Food Co., (Guangzhou, China). Starters: *Streptococcus thermophilus* and *Lactobacillus bulgaricus* (*Lactobacillus dechellii Bulgarian subspecies*) (viable bacteria count was about 1×10^9 CFU/g) were provided by Danisco (China) Co., Ltd, (Shanghai, China). MRS medium was purchased from Shanghai Mingrui Biotechnology Co., Ltd, (Shanghai, China). Agar was purchased from Xi'an Huibang Bioengineering Co., Ltd, (Xi'an, China). All other chemicals were used of analytical grade.

The preparation of yogurt samples refers to the previous experimental methods of the author (Qu et al., 2021).

Take a certain quality (M_1) of yogurt in a centrifuge tube; centrifuge at 4 000 r/min for 25 min at 4 °C, discard the supernatant and weigh the remaining mass (M_2). It is not easy to separate whey from yogurt with good water-holding capacity during storage (Aboushanab et al., 2018).

The calculation formula is as follows:

$$\boldsymbol{WHC}\,(\%) = \boldsymbol{M_2} \div \boldsymbol{M_1} \times \boldsymbol{100\%} \quad (1)$$

Determination of acidity by an acidimeter (PB-10, Seidolis instruments, Germany): set-type yogurt samples were taken every 1 h during the fermentation process and the yogurt samples were determined after being stored 24 h. Then, 10 g yogurt samples were put into a 250 mL triangle bottle and 20 mL distilled water was added to dilute and mixed, 0.5% phenolphthalein was added as an indicator and titrated with 0.1mol/L NaOH standard solution until it was slightly red. Not fading within 30 s marked the end of determination. Consuming 0.1 M of NaOH is equal to 1 °T.

All pH values were monitored after adding starter bacterial cultures using a digital pH meter (Thermol Scientific Inc., USA).

The viscosity of yogurt was measured at 4 °C with a spindle (No. 3) rotation of 1500 rpm using the digital display rotating viscometer (NDJ-8S, Shanghai Yueping Scientific Instrument Co., Ltd., Shanghai, China). The readings were recorded at the 20th s of the measurement. The measurements were made in triplicate.

The experiments were performed by a texture analyzer (TA-XT.plus Texture Analyzer; Stable Micro Systems, Godalming, UK). Refer to Bedani et al., Ciron et al. (2010) and other methods, slightly improved. The yogurt samples were placed in 25 mL beakers and the Texture Profile Analysis (TPA) test mode and P/0.5 probe were used to determine the gel structure of the fermented milk. The parameters are as follows: the speed is divided into 2.0 mm/s before measurement, 1.0 mm/s during measurement, and 2.0 mm/s after measurement. Test samples shall be made in triplicate.

Microbial Analyses. The 1 g of yogurt with 9 mL of 0.9% (w/v) NaCl was mixed and diluted to a concentration of 10^4, 10^5, and 10^6, and then 1 mL of each dilution was inoculated on plates containing the MRS agar. Bacteria were counted by the pour plate technique. The plates in duplicates were incubated anaerobically at 37 °C for 72 h, and then colonies were counted (Rosburg et al., 2010; Gebara et al., 2015; Ladjevardi et al., 2016).

According to the relevant sensory evaluation methods of the national standard, 10 volunteers (5 men and 5 women) with sensory evaluation experience of fermented milk were selected to conduct the sensory evaluation of fermented milk added with OG from the aspects of color, structural state, texture, and flavor. The full score was 100 and the sensory score was the average score of 10 people.

Unless otherwise stated, all tests were performed in triplicate, and data were averaged. Standard deviation was also calculated. SPSS version 17.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical evaluations, and OriginPro 8.6.0 (Originlab, Northampton, Massachusetts, USA) was used for the construction of the graphs. The sensory evaluation and yogurt WHC with different storage times of OG were analyzed by independent sample t-test of SPSS 17.0 software. The significance (*P* values) of the microbiological parameters were calculated by the general linear model. One-way ANOVA was used to analyze the titration acidity of yogurt for different storage time, LSD and Dunnett's T3 test were applied for multiple comparisons and differences were considered to be statistically significant at $P < 0.05$.

Results of the research and their discussion.

For water-holding capacity values, a significant decrease was observed in the control yogurt, while a slight decrease was observed in 0.3% OG yogurt (Fig. 1 (a)). This can be attributed to the hydration properties of OG, which have an impact on the shelf life of food products by preventing texture loss and avoiding syneresis problems.

As can be seen from Fig. 1 (b), the acidity of both control yogurt and 0.3% OG yogurt significantly increased to 93.8 ± 1.2 during 7 d of storage. And then (7–21 d of storage), no significant ($P \leq 0.05$) changes were observed in acidity values. An opposite trend was observed for pH values and reached the minimum (about 4.21 in control yogurt and about 4.18 in 0.3% OG yogurt) (Fig. 1 (c)). The decrease in pH values during the storage period might be mainly due to the utilization of OG by viable probiotic bacteria and the production of lactic acid. In addition, small amounts of CO_2 and formic acid from lactose may also lead to a decrease in pH (Deshwal et al., 2021; Zhao et al., 2021). All pH values ranged from 4.18 to 4.28, which are within the normal ranges for set-type yogurts.

Fig. 1 (d) shows the changes in viscosity values over 21 d of storage. Significant differences were noted between control yogurt and 0.3% OG yogurt. In general, the viscosity values increased throughout storage in concentrated and non-fat plain yogurt throughout storage (Agyemang et al., 2020; Kaur & Riar, 2020). The increasing viscosity during storage could be due to the protein rearrangement and protein-protein contact. The 0.3% OG yogurt had a higher viscosity than the control yogurt, and the highest values were 58560 ± 2120 cp at 21 d for 0.3% OG yogurt. This change could be attributed to the fact that OG has the ability to entrap water within the product. On the other hand, the addition of 0.3% OG could improve the protein rearrangement and protein-protein contact.

Live and active probiotic bacteria are considered to be beneficial for human health (Westerik et al., 2019; Meybodi et al., 2020). OG is considered to be prebiotic and may

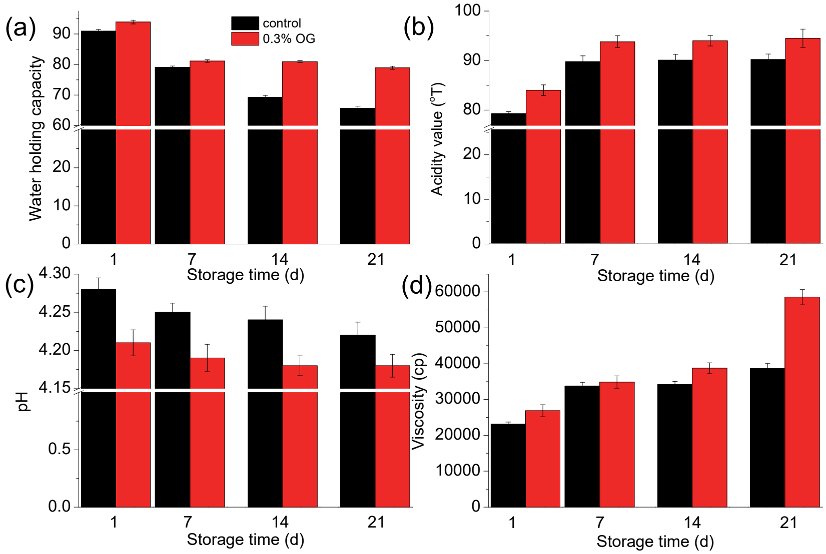

Fig. 1. The WHC (a), acidity value (b), pH (c), and viscosity (d) of yogurt

contribute to the activity of probiotic bacteria. So, the viability of probiotic bacteria in yogurts was checked. As shown in Fig. 2, during the whole storage period, the content of probiotics decreased, which was only 0.63 ± 0.05 $\times 10^7$ CFU/mL at 21 d. However, 0.3% OG yogurt contained significantly more live probiotic bacteria compared to the control one ($P \leq 0.05$) throughout the whole cold storage period. The viability of probiotic bacteria of 0.3% OG yogurt at 14 d (3.18 ± 0.2 $\times 10^7$ CFU/mL) was only slightly lower than that of the control yogurt at 1 d (3.45 ± 0.3 $\times 10^7$ CFU/mL). Similar results have also been reported (Ladjevardi et al., 2016). This fully demonstrates that the addition of OG has a protective effect on probiotics in yogurt. The survival of yogurt microbiota in 0.3% OG yogurt will be beneficial for human health.

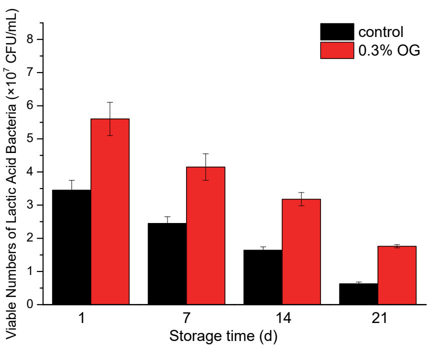

Fig. 2. The viability of probiotic bacteria in yogurts during the storage

The textural parameters of yogurt are important for yogurt products, as they can simulate their breakdown occurring in the mouth. Results of texture profile analysis (TPA) of yogurts, including hardness (N), consistency, cohesiveness, and springiness (%) are summarized in Table 1. For both control yogurt and 0.3% OG yogurt, the hardness of yogurts was improved, while the adhesiveness and gumminess values declined during the storage. The textural characteristics of yogurts are affected by the addition of 0.3% OG.

The evaluation index of yogurt is mainly the hardness. The hardness of 0.3% OG yogurt was higher than that of control yogurt, especially after 21 days of storage (50.45 in 0.3% OG yogurt and

40.99 in the control yogurt). The higher hardness values could be attributed to the ability of the OG to entrap water, and maintain structure within the product (Kaur & Riar, 2020; Summo et al., 2020).

In contrast, the adhesiveness of 0.3% OG yogurt was lower than that of the control yogurt, especially after 21 d of storage (-11.85 in 0.3% OG yogurt and -10.39 in the control yogurt). The decrease in adhesiveness may be due to the fact that OG can reduce adherence of the yogurt with teeth during chewing.

The 0.3% OG yogurt had a slight increase in gumminess as compared to the control yogurt. And, during storage, an increase in gumminess was observed, which might be due to the increased hardness of yogurts. Similar behavior was found for cohesiveness, which can be attributed to the fact that OG has the ability to form new gel structures with casein, effectively intercepting and entrapping water within the yogurt. No significant differences were obtained for springiness values between the control yogurt and 0.3% OG yogurt.

1. Results of TPA test in the control yogurt and 0.3% OG yogurt

Test	Days	Yogurt samples	
		control yogurt	0.3% OG yogurt
Hardness	1	21.14	22.85
	7	24.77	28.36
	14	28.76	35.99
	21	40.99	50.45
Adhesiveness	1	-8.23	-9.15
	7	-9.18	-10.21
	14	-9.25	-11.37
	21	-10.39	-11.85
Gumminess	1	9.26	13.78
	7	12.79	13.81
	14	14.71	19.82
	21	21.54	13.78
Cohesiveness	1	0.43	0.43
	7	0.41	0.44
	14	0.51	0.57
	21	0.53	0.59
Chewiness	1	8.75	9.46
	7	11.39	12.87
	14	14.06	13.77
	21	20.72	18.99
Springiness	1	0.94	0.92
	7	0.95	0.93
	14	0.95	0.95
	21	0.96	0.97

2. Sensory properties of the control yogurt and 0.3% OG yogurt during storage

Variables	Days	Yogurt samples	
		control yogurt	0.3% OG yogurt
Color	1	8.12 ± 0.24	8.71 ± 0.46*
	7	8.13 ± 0.34*	8.68 ± 0.32**
	14	8.18 ± 0.28*	8.51 ± 0.48**
	21	8.20 ± 0.14*	8.50 ± 0.28*
Structural state	1	26.05 ± 0.47	26.78 ± 0.63**
	7	27.05 ± 0.12*	27.32 ± 0.76*
	14	27.02 ± 0.32*	28.08 ± 0.92**
	21	27.08 ± 0.28*	27.98 ± 0.88*
Texture	1	24.28 ± 0.39	24.97 ± 0.79**
	7	24.92 ± 0.22*	25.12 ± 0.82*
	14	25.04 ± 0.28*	25.98 ± 0.70**
	21	24.88 ± 0.40**	25.88 ± 0.70**
Flavor	1	23.7 ± 0.90	24.67 ± 0.47**
	7	23.1 ± 0.70*	24.02 ± 0.32**
	14	23.0 ± 1.20**	24.12 ± 0.22*
	21	23.1 ± 1.20**	23.88 ± 0.28*

In short, results of textural profile tests showed appropriate hardness, less gumminess, less adhesiveness, and less destruction in 0.3% OG yogurt, giving a firm and creamy texture that was near to creamy mouthfeel of full-fat yogurt, improving the mouthfeel characteristics thereby enhanced sensory appeal for the product in which incorporated.

The sensory properties of the yogurts are shown in Table 2. All yogurts had average sensory scores of above 80, indicating a preference both for the control yogurt and 0.3% OG yogurt throughout storage.

The sensory results indicated that there was a statistically significant ($P \leq 0.05$) difference in sensory characteristics between the control yogurt and 0.3% OG yogurt. The control yogurt had the highest acceptability value of 83.26 at 21 d of storage, while 0.3% OG yogurt had the highest acceptability value of 86.49 at 21 d of storage. Clearly, the addition of 0.3% OG has a positive effect on the acceptability of the yogurt, independently of the storage time.

Conclusions.

The results of the present work showed that 0.3% oat β-glucan yogurt has good sensory and mouthfeel characteristics by improving viscosity and texture as compared to the control. Due to the lack of dietary fiber in milk and yogurt, β-glucan is a suitable choice for dairy systems. The 0.3% oat β-glucan yogurt also has high nutritional values as oat β-glucan can act as a prebiotic in probiotic yogurt. Therefore, yogurt containing 0.3% oat β-glucan could be an innovative healthy dairy product for enhancing oat β-glucan consumption.

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Abstract. *Досліджено доцільність збагачення йогурту 0,3% вівсяним β-глюканом. Результати досліджень показали, що йогурт із додаванням 0,3% вівсяного β-глюкану володіє водоутримуючою здатністю. Під час зберігання, значення кислотності та pH досягали максимальних значень упродовж 7 діб, а після 7 доби значних змін не спостерігалося. Усі значення pH становили від 4,18 до 4,28, що є в межах норми для йогуртів. Цікаво, що показники в'язкості зростали впродовж усього періоду зберігання. Відмічали значні відмінності між контрольним йогуртом та йогуртом із додаванням 0,3% вівсяного β-глюкану. Експериментальний зразок мав вищу в'язкість, ніж контрольний йогурт, а найвищі значення були 58560 ± 2120 cp на 21 добу для йогурту з додаванням 0,3% вівсяного β-глюкану. Перевірено життєздатність пробіотичних бактерій у йогуртах. Упродовж усього терміну зберігання вміст пробіотиків знижувався, становив лише 0,63 ± 0,05 ×107 КУО/мл на 21 добу. Проте йогурт із додаванням 0,3% вівсяного β-глюкану містив значно більше живих пробіотичних бактерій, порівнюючи з контролем, упродовж усього періоду зберігання в охолодженому стані. Життєздатність пробіотичних бактерій йогурту з додаванням 0,3% вівсяного β-глюкану на 14 добу (3,18 ± 0,2 ×107 КУО/мл) була лише незначно нижчою, ніж у контрольного йогурту на 1 добу (3,45 ± 0,3 ×107 КУО/мл). Це повністю демонструє, що додавання 0,3% вівсяного β-глюкану чинить захисну дію на пробіотики в йогурті, що буде корисно для здоров'я людини. На текстурні характеристики йогурту вплинуло додавання 0,3% вівсяного β-глюкану, що призвело до зниження адгезивності, але посилення твердості та клейкості під час зберігання. Усі йогурти мали середню сенсорну оцінку вище 80, що вказує на перевагу як контрольного йогурту, так і йогурту з додаванням 0,3% вівсяного β-глюкану під час зберігання. результати сенсорної оцінки показали, що йогурт із додаванням 0,3% вівсяного β-глюкану мав найвищі значення прийнятності 86,49 на 21 добу зберігання, що мало позитивний вплив на прийнятність йогурту, незалежно від терміну зберігання. Загалом, йогурт, що містить 0,3% вівсяного β-глюкану, може бути інноваційним молочним продуктом для здорового харчування.*

Ключові слова: *йогурт, вівсяний β-глюкан, сенсорні показники, в'язкість, хімічні характеристики*