THE EFFECT OF ADDED MELON PUREE AND XANTHAN GUM ON LOW-FAT PROBIOTIC YOGURT

Tanja Stojanovska
Faculty of Technology and Technical Sciences, Veles, Republic of North Macedonia,
tanja.b.stojanovska@uklo.edu.mk
Tatjana Kalevska
Faculty of Technology and Technical Sciences, Veles, Republic of North Macedonia,
tatjana.kalevska@uklo.edu.mk
Nevena Gruevska
Faculty of Technology and Technical Sciences, Veles, Republic of North Macedonia,
nevena.gruevska@uklo.edu.mk
Daniela Nikolovska Nedelkoska
Faculty of Technology and Technical Sciences, Veles, Republic of North Macedonia,
daniela.nedelkoska@uklo.edu.mk
Vezirka Jankuloska
Faculty of Technology and Technical Sciences, Veles, Republic of North Macedonia,
vezirka.jankuloska@uklo.edu.mk

Abstract: Yogurt is a popular fermented milk product consumed primarily for its nutritional value, health benefits, and therapeutic attributes. The addition of fruit to yogurt contributes to the improvement of its functional properties and affects syneresis and sensory quality. Hydrocolloids are often incorporated into yogurt during production to enhance its technological characteristics. Although there is research on the impact of added fruit in yogurt, there is a lack of data on the effect of melon puree added to yogurt after fermentation, with or without xanthan gum as a stabilizer. For this purpose, four yogurt samples were prepared: a commercial probiotic yogurt with 1% m.m. as the control sample (JP), a sample with 85% commercial probiotic yogurt and 15% melon puree (JD), a sample with 100% commercial probiotic yogurt and 0.15g xanthan gum (JK), and a sample with 85% commercial probiotic yogurt, 15% melon puree, and 0.15g xanthan gum (JDK). Physico-chemical parameters, including moisture %, water activity *(aw)*, active acidity (pH), titration acidity (ºSH), and syneresis, were analyzed in all samples during storage for 0, 3, and 6 days. The results are presented as $\bar{x}$ - mean value, ± Sd - standard deviation, from n-3 – number of repetitions. Sensory evaluation was also performed for all yogurt samples, assessing quality indicators such as appearance, color, taste, smell, aroma, and consistency. From the obtained results, we can conclude that the moisture content of all yogurt samples increased during storage. Melon puree increased syneresis in the JD sample, whereas the addition of xanthan gum in the JK sample led to a decrease in syneresis. However, the lowest syneresis values were observed in the JDK sample compared to the other samples, with 10.92 ± 0.064 and 18.06 ± 0.206 for the 0th and 6th days, respectively. This is likely a reflection of the synergistic effect of the melon puree and xanthan gum. The water activity (*aw*) of all samples during the analyzed periods ranged from 0.980 ± 0.001 to 0.974 ± 0.005, indicating minimal influence from the added melon puree and xanthan gum. The addition of xanthan gum in the JK sample led to a reduction in both pH value and titration acidity (ºSH), while higher values for these parameters were observed in the JD sample due to the addition of melon puree. Sensory evaluation revealed that the highest-rated samples were J and JK, which, with average weighted scores of 4.8 and 4.69, respectively, were classified as excellent quality products.
Keywords: Fruit yogurt, melon puree, xanthan gum, water activity, active acidity, titration acidity, syneresis, sensory analysis

1. INTRODUCTION

Yogurt is a popular fermented dairy drink enjoyed in many parts of the world (Bankole et al., 2023). The popularity and high consumption of yogurt are primarily due to its nutritional value and its health and therapeutic properties (Park et al., 2019). From a nutritional point of view, yogurt is very similar to the dairy from which it is made, partially changed, with certain therapeutic effects, related to starter cultures added to the production process (Kalevska et al., 2019). Yogurt acts as a probiotic carrier and contains nutritionally rich fats, high levels of biologically important proteins, calcium, zinc, magnesium, phosphorus, riboflavin (B_2), thiamin (B_1), vitamin B_6, vitamin B_{12}, niacin as well as folic acid (Matela et al., 2019). Quality yogurt should be smooth, with a shiny surface, free from lumps and cracks, without whey separation (syneresis), and without an undesirable odor (Boghra &

Mathur, 2000). Also, the taste, texture and aroma of yogurt depend on the country of origin, the quality of the raw materials and the production process (Hossain et al., 2012).

The addition of fruit to yogurt before fermentation improves its functional properties (Fernandez & Marette, 2017) and also affects viscosity, syneresis, and sensory quality (Najgebauer-Lejko, 2014; Othman et al., 2019). The pectins and fructose from the fruit enhance the consistency and viscosity of the yogurt, improving the mouthfeel. They reversibly adsorb to casein, causing an increase in steric hindrance and thus a decrease in aggregation (Roy et al., 2015; Amal et al., 2016; Forena et al., 2024). From a nutritional point of view, fruit is a rich source of carotenes, lycopene, phenolic compounds, antioxidants, minerals and vitamins (Jideani et al., 2021; Rahaman et al., 2023). Melon *(Cucumis melo L.)* is an annual diploid plant belonging to the *Cucurbitaceae* (Nunez-Palenius et al., 2008). Its composition includes 6-12% of sugar, vitamins B_1, B_3, C, folic acid and iron. The vitamin C content in melons is three times greater than that in watermelon. Whereas, iron absorption from melon is 17 times greater than from milk and twice as great as from chicken (Khujayeva et al., 2024).

In addition to fruit, additives are often incorporated into yogurt to improve its technological characteristics (Bankole et al., 2023). Hydrocolloids have long been the focus of scientific interest. The global hydrocolloid market was estimated at USD 11.2 billion in 2023 and is expected to reach USD 14.5 billion by 2028 (Zhang et al., 2024). Xanthan gum (E415) is a complex extracellular polysaccharide synthesized by the bacterium *Xanthomonas campestris* and is known for its superior rheological properties (Berninger et al., 2021). Xanthan gum is used in yogurt production to improve texture, increase firmness, and prevent syneresis (El-Sayed et al., 2002). Its popularity is due to the ability to reduce syneresis without affecting pH and active acidity, while improving the texture of yogurt is without altering sensory characteristics (Mohsin et al., 2019).

Although most authors explore the impact of added fruit in yogurt before fermentation Sengupta et al., (2014); Amal et al., (2016); Kamber & Harmankaya, (2019), there is still a lack of data on the impact of added melon pure in yogurt after fermentation, without or in combination with xanthan gum, as a stabilizer. For this purpose, we analyzed commercial probiotic yogurt with 1% milk fat, both with and without the addition of melon pulp and xanthan gum.

2. MATERIAL AND METHODS

Materials

The materials for this research included commercial probiotic yogurt with 1% milk fat and melon, both purchased from a local market in the Republic of North Macedonia. Xanthan gum was produced by Foodchem, phenolphthalein by Fisher Chemical, and NaOH by Alkaloid, Macedonia.

Fruit preparation

The preparation of the fruit includes washing, peeling and separating the seeds from the melon. Using a blender, the melon is pureed, and the liquid phase is decanted. The solid phase is then blanched at 83 ± 1°C for 3 minutes. After refrigeration, it is stored in a sterile bottle and stored in a refrigerator at a temperature of 4°C until its use.

Sample preparation

Five samples were analyzed: melon puree (DP); commercial probiotic yogurt with 1% m/m as the control sample (JP); 85% commercial probiotic yogurt with 1% m/m plus 15% melon puree (JD); 100% commercial probiotic yogurt with 1% m/m and 0.15 g xanthan gum (JK); and 85% commercial probiotic yogurt with 1% m/m plus 15% melon puree and with the addition of 0.15 g xanthan gum (JDK). Samples are prepared in the amount of 2L. The prepared samples were stored in sterile glass bottles and refrigerated at 4°C until analyses were carried out on days 0, 3 and 6 of storage. From each samples n-3 probes were analyzed.

Methods

The water activity *(aw)*, in the tested yogurt samples was determined using a LabTouch-aw device from Novasina. Moisture content was determined according to Roy et al., (2015), using a DRY-Line dryer, in VWR production. Active acidity (pH) was measured using laboratory pH Meter PL-600, in MRC production, the sample was prepared according to Matela et al., (2019), while titration acidity ºSH was determined according to (Tomovska et al., 2016). The syneresis of the yogurt samples is determined according to (Amal, et al., 2016). Sensory evaluation of yogurts was conducted according to the system of scoring corrected five-point score, according to Radovanovic & Popov-Raljic (2000/2001), by 20 evaluators of different sexes and ages. Statistical processing and calculations were done in Excel, as $\bar{x}$ - mean ± Sd - standard deviation, from n-3 number of samples.

3. RESULTS AND DISCUSSION

Table 1 presents the results of the physico-chemical analyses of the melon pure and yogurt samples (JP, JD, JK and JDK) during storage of 0, 3 and 6 days are presented. The moisture content of the melon pure was 80.72±0.05%, the water activity 0.971 ±0.005 and the pH value 5.96±0.01. According to, Gouda et al., (2020), the pH of the pulp of

Japanese persimmon, mango and guava were 5.2, 4.53 and 3.7, respectively. The lowest titration acidity of 28.2±1.410 °SH on the 6th day was determined in yogurt JK, and the highest in JKD 37.2± 0.305, which is approximate to the titration acidity of 38˚SH that they determined in yogurt (Kalevska et al., 2019).

During storage from 0 to 6 days in the JP control sample, the moisture content increased from 90.94±0.10% to 93.34±1.95%. The addition of 15% melon pure to the JD yogurt contributed to a decrease in moisture content relative to the JP yogurt control sample during storage. The addition of 15% papaya pulp contributed to a decrease in moisture content of 89% to 85.12% (Amal et al., 2016). The increase in dry matter content of fruit yogurt was proportional to the added percentage of fruit puree (Blassy et al., 2020). The addition of 0.15% xanthan to the JK sample affected a decrease in moisture by 0.09% compared to the JP sample on day 0. However, during the storage period of the yogurt, the moisture content of the JK sample increased. Increases in the moisture content of yogurt with added xanthan during storage were also reported and El-Sayed et al., 2002 and Hematyar et al., 2012. In contrast, the moisture content of the JDK sample decreased during storage, with the lowest moisture content measured on day 6 compared to the other yogurt samples and storage periods studied.

Table 1. Results of physico-chemical analysis of pureed melon and yogurt samples

Samples/storage time		% Moisture	*aw*	pH	°SH	% Syneresis
DP	Day 0	80.72±0.05	0.971±0.005	5.96±0.01	/	/
JP	Day 0	90.94±0.10	0.980±0.001	4.37±0.005	26.6±0.195	21.64±0.092
	Day 3	91.34±0.13	0.978±0.001	4.37±0.030	27.8±0.351	21.90±0.802
	Day 6	93.34±1.95	0.975±0.003	4.33±0.005	29.2±0.251	26.16±0.305
JD	Day 0	89.23±0.53	0.978±0.001	4.46±0.015	27.4±0.203	24.82±0.030
	Day 3	90.04±0.05	0.977±0.001	4.43±0.055	25.4±0.451	27.55±0.180
	Day 6	90.28±0.15	0.974±0.005	4.40±0.015	36.4±0.208	27.35±0.397
JK	Day 0	90.85±0.12	0.978±0.001	4.34±0.036	24.2±0.210	22.49±0.030
	Day 3	91.42±0.05	0.977±0.005	4.26±0.072	26.5±0.264	13.33±0.091
	Day 6	91.18±0.62	0.976±0.001	4.23±0.015	28.2±1.410	17.28±0.065
JDK	Day 0	89.55±0.10	0.977±0.005	4.42±0.021	26.6±0.251	10.92±0.064
	Day 3	90.23±0.28	0.976±0.005	4.37±0.030	28.9±0.416	7.35±0.036
	Day 6	89.92±0.06	0.975±0.001	4.34±0.011	37.2±0.305	18.06±0.206

DP - melon, JP-100% yogurt, JD-85% yogurt + 15% melon pulp, JK-100% yogurt + 0.15g xanthan gum and JDK-85% yogurt 15% melon pulp + 0.15g xanthan gum.

Source: Authors research

Syneresis is one of the basic defects of yogurt, characterized by the accumulation of serum or whey on its surface (Alsaleem et al., 2024). The JD sample is characterized by the highest percentage of syneresis, which increased during storage from 24.82 ± 0.030% to 27.35 ± 0.397%. An increase in syneresis due to the addition of 15% papaya is also reported by Amal et al., (2016), while according to Sengupta et al., (2014), the addition of watermelon juice reduces syneresis compared to the control sample from 36.54% to 28.78%. The addition of 0.2% xanthan gum to low-fat yogurt resulted in an increase in syneresis from 37% to 41% during 7 days of storage (Alsaleem et al., 2024). In contrast, our findings showed a decrease in syneresis in the PK sample, from 22.49 ± 0.030% to 17.28 ± 0.065% during storage. The decrease in syneresis is attributed to increased tension in the yogurt due to protein interactions with the added xanthan gum (El-Sayed et al., 2002). An increase in xanthan gum concentration from 0.2% to 1% significantly reduced syneresis ($p < 0.05$) during 21 days of storage (Alsaleem et al., 2024). The JDK sample is characterized by the lowest values for syneresis, which we attribute to the synergistic action of melon puree and xanthan gum.

The water activity *(aw)* in all samples in the analyzed periods ranged from 0.980±0.001 to 0.974±0.005, in all samples of the three test periods, indicating a minimal impact of the added melon puree and xanthan gum of the *aw* value. The highest initial value was measured in the JP control sample, while the lowest was found in the JDK sample. It is also interesting to note that the *aw* value in all samples of yogurt decreases during storage.

the pH value of the JP sample ranged from 4.37±0.005 on day 0 and 4.33±0.005 on day 6. The decrease in pH value is expected and occurs as a result of the development of lactic acid bacteria and the production of lactic acid (Wang et al., 2021). A decrease in pH was observed in all yogurt samples during storage. The addition of melon pulp influenced an increase in the pH value of JD, as a result of the higher pH value of cantaloupe pulp. The pH value of fruit yogurt is dependent on the pH value of the added fruit (Blassy et al., 2020). In strawberry, peach, apricot and banana fruit yogurts, the following pH values, 3,872, 4,380, 4,400 and 4,326, respectively, were measured on the 1st day of storage (Kamber & Harmankaya, 2019). The JK sample showed lower pH values relative to JP over the entire storage period. According to Rafiq et al., (2020), added xanthan affects a decrease in pH, which decreases proportionally with an increase in the added amount of xanthan (Alsaleem et al., 2024). While in the JDK sample, the pH ranged from 4.42±0.021 to 4.34±0.011.

Titration acidity ºSN increased in all yogurt samples during storage. The largest increase in titration acidity was observed in the JD and JDK samples, which we hypothesize was due to the added fruit. The increase in titration acidity due to added fruit is confirmed in their studies by Sengupta et al., 2014; Roy et al., 2015; Kamber & Harmankaya, 2019. In contrast, Amal et al., (2016) indicate a decrease in titration acidity by increasing the percentage of added fruits (papaya and pear cactus). The added xanthan in the JK sample contributed to a lower value for titration acidity relative to the control, which is confirmed by Rafiq et al., 2020.

In Table 2, the results of sensory evaluation of the JP, JD, JK, and JDK samples are presented with the following quality indicators: appearance, color, taste, smell, aroma, and consistency of the yogurts. The addition of melon puree contributed to a decrease in the color, taste, smell, aroma, and consistency scores of the JD and JDK samples compared to the JP and JK samples. On the other hand, the added xanthan in JK contributed to an improved appearance compared to other samples.

Table 2. Results of sensory evaluation

Quality Index	CV	Score JP	Score JD	Score JK	Score JDK
Appearance	4	4.485	4.500	4.875	4.375
Color	2	5.000	4.375	4.875	4.375
Taste	4	4.750	3.000	4.625	3.375
Smell	3	4.750	3.000	4.375	3.250
Aroma	3	4.750	3.125	4.625	3.250
Consistency	4	4.750	3.625	4.750	3.875
Overall score	Σ20				
Weighted mean score		4.8	3.58	4.69	3.74
% of possible quality		96	71.62	93.75	74.75

Source: Authors research

According to the German Standard for Sensory Assessment (Deutsche Landwirtschafts-Gesellschaft-DLG), weighted mean scores are categorized as follows: excellent quality with a score of 4.5 to 5.0, very good quality with a score of 3.5 to 4.5, good quality with a score of 2.5 to 3.5, and not meeting quality requirements with a score of less than 2.5 (Nakov et al., 2018). Comparatively, the DLG samples of JP and JK yogurt characterized by mean weighted scores of 4.8 and 4.69, respectively, fall into the category of excellent quality products. The JD and JDK samples are categorized as very good quality products, with weighted mean scores of 3.58 and 3.74, respectively. The higher percentage of 96% control yogurt compared to JD and JDK yogurts of 71%, 62%, and 74.75% respectively, indicates consumers' consumption habits of classic yogurt compared to yogurt with added fruits.

4. CONCLUSION

The addition of 1.5% xanthan and 15% melon puree to low-fat probiotic yogurt after fermentation affects moisture content, syneresis, active and titration acidity. That is, during storage, the moisture content of all yogurt samples increases. Melon puree increased syneresis in the JD sample, while the addition of xanthan gum to the JK sample contributed to a decrease in syneresis. The lowest values for syneresis were observed in the JDK sample, with 10.92±0.064 on day 0 and 18.06±0.206 on day 6. The water activity *aw* in all samples in the analyzed periods ranged from 0.980±0.001 to 0.974±0.005, indicating a minimal impact of the added melon puree and xanthan gum. The addition of xanthan to the JK sample affects a decrease in pH value and titration acidity ºSH, while higher values for these parameters are observed in the JD sample due to the added melon puree. The addition of melon puree also influenced the sensory acceptability of the yogurts, placing the JD and JDK samples in the category of very good quality products. The added xanthan 0.15% had little impact of sensory perception and placed the JK sample in the category of products of excellent quality. Concerning the process of designing a new food product, further studies are needed toward the nutritional characterization and understanding the functional properties of the products.

REFERENCES

Alsaleem, K. A., & Hamouda, M. E. (2024). Enhancing Low-Fat Probiotic Yogurt: The Role of Xanthan Gum in Functionality and Microbiological Quality. *Processes*, *12*(5), 990.

Amal, A., Eman, A., & Nahla, S. Z. (2016). Fruit flavored yogurt: Chemical, functional and rheological properties. *International journal of environmental and agriculture research*, 2(5), 57-66.

Bankole, A. O., Irondi, E. A., Awoyale, W., & Ajani, E. O. (2023). Application of natural and modified additives in yogurt formulation: Types, production, and rheological and nutraceutical benefits. *Frontiers in Nutrition*, *10*, 1257439

Berninger, T., Dietz, N., & González López, Ó. (2021). Water-soluble polymers in agriculture: xanthan gum as eco-friendly alternative to synthetics. *Microbial Biotechnology*, *14*(5), 1881-1896.

Blassy, K., Hamed, M., & Gouda, M. O. A. (2020). Functional low fat fruit yoghurt. *Ismailia Journal of Dairy Science & Technology*, *7*(1), 11-20.

Boghra, V. R., & Mathur, O. N. (2000). Physico-chemical status of major milk constituents and minerals at various stages of shrikhand preparation. *J Food Sci Technol*, 37, 111-115.

El-Sayed, E., Abd El-Gawad, I., Murad, H., & Salah, S. (2002). Utilization of laboratory-produced xanthan gum in the manufacture of yogurt and soy yogurt. *European Food Research and Technology*, *215*, 298-304.

Fernandez, M. A., & Marette, A. (2017). Potential health benefits of combining yogurt and fruits based on their probiotic and prebiotic properties. *Advances in Nutrition*, *8*(1), 155S-164S.

Forena, R., Nisa, F., & Prasmita, H. (2024). The effect of carboxymethyl cellulose (CMC) and banana puree (Musa acuminata Colla) addition on the characteristics and microstructure of goat milk yogurt. In *BIO Web of Conferences* (Vol. 90, p. 01004). EDP Sciences.

Gouda, A., Hamed, M., & Osman, K. B. M. (2020). Functional properties of yoghurt fortified with fruits pulp. *Ismailia Journal of Dairy Science & Technology*, *7*(1), 1-9.

Hematyar, N., Samarin, A. M., Poorazarang, H., & Elhamirad, A. H. (2012). Effect of gums on yogurt characteristics. *World Applied Sciences Journal*, *20*(5), 661-665.

Hossain, M. N., Fakruddin, M., & Islam, M. N. (2012). Quality comparison and acceptability of yoghurt with different fruit juices. Journal of Food Processing & Technology, 3(8), 1-5.

Jideani, A. I., Silungwe, H., Takalani, T., Omolola, A. O., Udeh, H. O., & Anyasi, T. A. (2021). Antioxidant-rich natural fruit and vegetable products and human health. *International Journal of Food Properties*, *24*(1), 41-67.

Kalevska, T., Nikolovska Nedelkoska, D., Stamatovska, V., Uzunoska, Z., Martinovski, S., & Jankuloska, V. (2019). Evaluation of the quality of raw milk for yogurt production. *Journal Of Agriculture And Plant Sciences, Japs,* 17 (1), 105-109.

Kamber, U., & Harmankaya, S. (2019). The effect of fruits to the characteristics of fruit yogurt. *Pakistan Journal of Agricultural Sciences*, *56*(2).

Khujayeva, M., Ibadullayev, B., Kuramboyev, S., Radjapov, M., Achilova, S., Atajanov, S., & Buranova, S. (2024). Quality examination of ice cream products made from melon grown in Khorezm area. In *E3S Web of Conferences* (Vol. 497, p. 03021). EDP Sciences.

Matela, K. S., Pillai, M. K., & Thamae, T. (2019). Evaluation of pH, titratable acidity, syneresis and sensory profiles of some yoghurt samples from the kingdom of Lesotho. *Food Research*, *3*(6), 693-697.

Mohsin, A., Ni, H., Luo, Y., Wei, Y., Tian, X., Guan, W., & Guo, M. (2019). Qualitative improvement of camel milk date yoghurt by addition of biosynthesized xanthan from orange waste. *Lwt*, *108*, 61-68.

Najgebauer-Lejko, D. (2014). Effect of green tea supplementation on the microbiological, antioxidant, and sensory properties of probiotic milks. *Dairy science & technology*, *94*, 327-339.

Nakov, G., Koceva Komlenić, D., Ivanova, N., Damyanova, S., Godjevargova, T., & Šušak, A. (2018). Sensory analysis of biscuits from einkorn flour, barley flour, einkorn flakes and wheat flour in different proportions and different sugars. In *9th International Congress Flour-Bread'17 [and] 11th Croatian Congress of Cereal Technologists* (pp. 105-114). Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek.

Nunez-Palenius, H. G., Gomez-Lim, M., Ochoa-Alejo, N., Grumet, R., Lester, G., & Cantliffe, D. J. (2008). Melon fruits: genetic diversity, physiology, and biotechnology features. *Critical reviews in biotechnology*, *28*(1), 13-55.

Othman, N., Hamid, H. A., & Suleiman, N. (2019). Physicochemical properties and sensory evaluation of yogurt nutritionally enriched with papaya. *Food Res*, *3*(6), 791-797.

Park, Y. W., Oglesby, J., Hayek, S. A., Aljaloud, S. O., Gyawali, R., & Ibrahim, S. A. (2019). Impact of different gums on textural and microbial properties of goat milk yogurts during refrigerated storage. *Foods*, *8*(5), 169.

Radovanovic, R., Popov-Raljic, J. (2000/2001). Senzorna analiza prehrambenih proizvoda, Belgrad, 242-245.

Rafiq, L., Zahoor, T., Sagheer, A., Khalid, N., ur Rahman, U., & Liaqat, A. (2020). Augmenting yogurt quality attributes through hydrocolloidal gums. *Asian-Australasian journal of animal sciences*, *33*(2), 323.

Rahaman, M. M., Hossain, R., Herrera-Bravo, J., Islam, M. T., Atolani, O., Adeyemi, O. S., & Sharifi-Rad, J. (2023). Natural antioxidants from some fruits, seeds, foods, natural products, and associated health benefits: An update. *Food science & nutrition*, *11*(4), 1657-1670.

Roy, D. K. D., Saha, T., Akter, M., Hosain, M., Khatun, H., & Roy, M. C. (2015). Quality evaluation of yogurt supplemented with fruit pulp (banana, papaya, and water melon). International Journal of Nutrition and Food Sciences, 4(6), 695-699.

Sengupta, S.,Chakraborty, A., & Bhowal, J. (2014). Production and evaluation of yogurt with watermelon (Citrullus lanatus) juice. *Journal of International Academic Research for Multidisciplinary,* 2(5), 249-257.

Tomovska, J., Gjorgievski, N., & Makarijoski, B. (2016). Examination of pH, titratable acidity and antioxidant activity in fermented Milk, journal of materials science and engineering. *Journal of Materials Science and Engineering A*, *6*(11), 326-333.

Wang, Y., Wu, J., Lv, M., Shao, Z., Hungwe, M., Wang, J., Bai, X., Xie, J., Wang, Y., & Geng, W. (2021). Metabolism Characteristics of Lactic Acid Bacteria and the Expanding Applications in Food Industry. *Frontiers in bioengineering and biotechnology*, *9*, 612285.

Zhang, S., Ren, C., Wang, C., Han, R., & Xie, S. (2024). Effects of hydrocolloids and oleogel on techno-functional properties of dairy foods. Food Chemistry: X, 101215.