

Effect of Iron Fortification on the Physicochemical and Sensory Properties of Functional Yoghurt

“Najla H. Al-Garory¹ Raghad Saad Al-Musa^{2*} Alaa G. AL-Hashimi³

Zainab Abd Ali⁴

1,2,3,4 Department of food science, college of agriculture, university of Basrah, Basrah, Iraq.”

*Correspondence email: raghad.saad@uobasrah.edu.iq

Abstract

This research examined the effects of iron fortification on the functional yoghurt's chemical, physical, and sensory characteristics. At a concentration of 12% weight/volume, two distinct forms of advantageous iron salts ferrous sulfate T2 and ferrous bis-glycinate T3 were introduced. To provide a comparison, raw milk T1 was used as the control treatment. Tests including chemistry, physics, and rheology were conducted to evaluate the product's sensory qualities immediately after manufacturing and after it had been stored at 4°C for 3, 7, and 10 days. Following storage, the moisture contents of T1, T2, and T3 decreased, reaching 87.06%, 87.00%, and 87.7%, respectively. Meanwhile, the solids percentage increased to 10.98%, 11.70%, and 11.60%. There was an increase in the proportion of protein, fat, and ash after storage. Furthermore, it was observed that the peroxide value had a positive correlation with the advancement of the process. The storage periods were initially calculated to be 1.8, 1.88, and 1.87 MeqO₂/kg immediately after production. Subsequently, these values rose to 2.01, 2.16, and 2.15 MeqO₂/kg. Additionally, it was observed that the population of lactic acid bacteria progressively grew with the duration of storage, reaching 45 x 10⁶, 50 x 10⁶, 55 x 10⁶ CFU/ml at the start of storage. which increased to 75 x 10⁶, 90 x 10⁶, and 95 x 10⁶ CFU/ml after 10 days. T2 had the greatest values for viscosity, hardness, and whey separation, measuring 2890 cP, 99.80 g, and 6.8%, respectively. Following storage, the values show a rise, with T1 exhibiting the greatest overall sensory acceptance in comparison to treatments T2 and T3. The iron content had a substantial decline during the storage periods.

Keywords: Functional yoghurt, Iron, physicochemical properties, Peroxide value.

دراسة تأثير التديم بالحديد على الخواص الفيزيوكيميائية والحسية لليوكرت الوظيفي

نجلاء حسين الجاروري^١ ، رغد سعد الموسى^٢ ، الاء غازي الهاشمي^٣ ، زينب عبد علي^٤

قسم علوم الاغذية ، كلية الزراعة ، جامعة البصرة ، البصرة ، العراق

*Correspondence email: raghad.saad@uobasrah.edu.iq

الخلاصة

خلصت الدراسة الحالية الى تحديد تأثير التدعيم بالحديد على الصفات الفيزيوكيميائية والحسية لليوكرت الوظيفي بأضافة نوعين من املاح الحديد الآمنة صحيا بنسبة ١٢٪ / وزن / حجم وهي T2 ferrous sulfate و T3 ferrous bisglycineet فضلا عن معاملة السيطرة المصنعة من الحليب الخام T1. اجريت الفحوصات الكيميائية والفيزيائية والريولوجية وقيمت المعاملات حسيا بعد التصنيع مباشرة وعند الخزن في درجة حرارة ٤ م لمدة ٣ و ٧ و ١٠ يوم . بلغت قيم الرطوبة لكل من T1 و T2 و T3 على التوالي ٨٨.١٣ و ٨٧.٨٧ و ٨٨.١٦ ٪ وانخفضت القيم بعد الخزن بينما بلغت نسبة المواد الصلبة بعد التصنيع ١٠.٨٠ و ١١.٥٠ و ١١.٢٠ ٪ وقدرت نسبة البروتين والدهن والرماد لعينة السيطرة بعد التصنيع مباشرة ٣.٥٠ و ٣.٧٠ و ٠.٨٠ ٪ وقدرت T2 3.45 و ٣.٦٦ و ٠.٨٣ و T3 3.50 و ٣.٧٢ و ٠.٨٤ ٪ وارتفعت جميع القيم بعد الخزن ولوحظ زيادة قيمة البيروكسايدين بتقدم مدد الخزن اذ قدرت بعد التصنيع مباشرة ١.٨ و ١.٨٨ و ١.٨٧ ملى مكافئ/كغم وارتفعت القيم بعد الخزن كما لوحظ زيادة اعداد بكتريا حامض اللاكتيك بأزيداد فترة الخزن اذ بلغت فى بداية الخزن ١٠٦×٤٥ و ١٠٦×٥٠ و ١٠٦×٥٥ وارتفعت بعد الخزن وقدرت ١٠٦×٧٥ و ١٠٦×٩٠ و ١٠٦×٩٥ وحدة تكوين مستعمرة/ مل بعد ١٠ يوم . اظهرت T2 اعلى قيم للزوجنة والصلابة ونضوح الشرش ٢٨٩٠ سنتى بويز و ٩٩.٨٠ غم و ٦.٨ ٪ على التوالي وارتفعت القيم بعد الخزن وتفاوتت T1 بأعلى مجموع للتقبل الحسى بالمقارنة مع المعاملات T2 و T3 والتي بلغت على التوالي ٨٣ و ٨٣.٢ و ٨٥.٩ .

الكلمات المفتاحية : اليوكرت المدعم ، اليوكرت الوظيفي ، الاغذية الوظيفية ، البادئات ، قيمة البيروكسايدين

INTROUCTION

Functional foods are foods that contain particular levels of substances with biological activity and are non-toxic. They are designed to provide health or therapeutic benefits to enhance health and prevent chronic diseases. Newly developed functional foods include iron-fortified dairy products (Jurado-Guerra et al., 2023). A new generation of natural dairy products enhanced with health-promoting minerals and food additives has emerged in response to customers' growing concern for their well-being (S 'wiacder et al., 2020) including long-established dairy yoghurt (Wajs et al., 2023) and products of lactic acid bacteria fermentation. This mechanism yields health-promoting bacteriocins and physiologically active peptides. Yogurt contains proteins, lipids, carbohydrates, and salts and is rich in vitamins and minerals. (Moineau-Jean et al., 2019). Kamal et al. (2018) found that certain milk bacteria reduce pH, causing coagulation and providing functional, nutritional, and health advantages. Yoghurt, however, does not satisfy the daily need for Iron since its iron content is reduced by around 0.2% mg/kg (Al-Shaikh, 2018). As a heme component of hemoglobin and myoglobin, iron is an essential micronutrient. It is essential to the organism because it makes oxygen storage, transportation, and use easier (El-Kholy, 2011). Therefor fortifying yogurt with iron helps to counterbalance the nutritional shortfall of this mineral and improve its bioavailability (Preedy, 2013). Anemia is the result of iron deficiency, which also negatively impacts immunological response, childhood cognitive awareness, cognitive development, and general human health (Ziena and Nasser, 2019). According to the World Health Organization (WHO), anemia, a disorder marked by a lack of red blood cells or hemoglobin, affects around 30% of people worldwide. One way to manage iron deficiency and lessen the harmful effects of anemia is to fortify diet. Numerous studies have shown that the best and safest method to absorb iron is via yogurt

(Jayalalitha et al., 2022). The recommended daily iron intake for males is 19.3-20.5 mg, while for women is 17.0-18.9 mg. Before adding iron to several factors must be considered such as its impact on sensory quality, microbial populations, taste, shelf life, and fat oxidation (Ziena and Nasser, 2019). One food product that requires sophisticated heat treatment during manufacture is yogurt, which kills unwanted microbes, blocks toxic enzymes and extends storage life (Arnoldi, 2001). thermal treatments such as pasteurization and sterilization effectively eliminate disease-causing bacteria and spoilage, yet they induce detrimental effects on food quality due to heat exposure and high energy consumption (Li et al., 2021). Microwave heating stands out as an emerging technology employed in food processing, utilizing electromagnetic waves within the frequency range of 300 MHz to 300 GHz. This method offers faster heating times by virtue of volumetric heating (Guo et al., 2017). The present study examines the sensory and physicochemical aspects of fortified cow milk yoghurt throughout manufacturing and storage to improve its nutritional value, and to provide daily iron demands while treating dairy product iron deficiencies.

MATERIAL AND METHODS

Milk Source

Raw cow's milk was prepared from the agricultural research station at the College of Agriculture / University of Basra.

Yoghurt Manufacturing

Yoghurt was made according to the method mentioned by (Panesar and Shinde 2011) with some modifications for three milk samples. The first sample was supplemented with 63mg/kg ferrous bis-glycinate T2. The second sample contained 83 mg/kg ferrous sulfate T3 at a rate of 12% w/v, while the control sample was free of T1 additives. Heat the milk to 60°C and double homogenize it at 2000 and 500 psi. Then, the milk was heated to 85°C for 5 minutes, then cooled to 42°C, inoculated with the activated starter in the quantity indicated by the producing company at a rate of 0.02%, and incubated at 42°C for 4 hours until coagulation (Ziena and Nasser, 2019). The yoghurt was stored in the refrigerator at 4°C. Physicochemical, rheological, and peroxide number tests were conducted, and the samples were evaluated sensory after 0, 3, 7, and 10 days.

Physicochemical and Rheological Tests

Chemical composition

Using an Eko milk analyzer, we were able to measure the percentages of fat, protein, solids, moisture, and ash in both the dry milk and the yoghurt (Dutch origin) (Coroian et al., 2019).

Estimation of pH and Total Acidity

Estimate the pH using a German-made Sartorius pH meter. The total acidity was estimated according to what was stated in (A.O.A.C. 2008) by titration with a 0.1 N sodium hydroxide solution in the presence of evidence of phenolphthalein.

Microbiological Tests

Estimation of the Number of Lactic Acid Bacteria

The method mentioned by Dave and Shah (1996) was followed to estimate the number of lactic acid bacteria using an M.R.S. agar medium with a pH of 4.5. The plates were incubated under anaerobic conditions at a temperature of 37°C for 48 hours.

Estimation of Peroxide Value

The peroxide value was estimated according to what was stated in (A.O.A.C. 2008).

Rheological Tests for Yoghurt

The viscosity of the samples was estimated according to the method mentioned by Liptak (2003) using a DVII viscometer produced by Brookfield Engineering Lab Inc., Stough, and Mass. Hardness was estimated using a Testometric M350-10CT Texture Analyzer (Panesar and Shinde, 2011). Whey purity was estimated according to the method described by Panesar and Shinde (2011) by placing 20 g of the treatments in a plastic tube, centrifuging it at a speed of 1000 rpm for 15 minutes, and weighing the filtrate.

Estimating the Amount of Iron

Atomic absorption spectrophotometer was used to measure Iron in parameters at a wavelength of 213.9 nm (Horwitz and Catimer, 2005).

Sensory Evaluation

Using a form that included the qualities of look, texture, flavor, aroma, and overall acceptability, ten specialized evaluators from the Department of Food Sciences/College of Agriculture/University of Basra assessed the samples' sensory qualities (Soad et al., 2014) with some modifications. Statistical Analysis

Applying C.R.D. to the data, we used Genstat's version 12.1's ANOVA analysis table and L.S.D. test to determine, at the 0.05 level of probability, if there were statistically significant differences between the averages of the coefficients (Schmuller, 2017).

RESULTS AND DISSCUSION

Chemical composition

Table (1) shows the percentages of moisture, solids, protein, fat, and ash for the control treatment T1 and the yoghurt treatments fortified with iron T2 ferrous sulfate and ferrous bisglycinet T3 after 0, 3, 7, and 10 days. It is noted that there are significant differences between the treatments for the percentages of moisture, solids, protein, and fat. There are no significant differences in the ash content at the probability level of $P < 0.05$, as the reinforcement or type of Iron used did not affect the chemical content between the treatments. The moisture percentage for treatments T1, T2, and T3, respectively, was 88.13, 87.87, and 88.16%. The percentages

decreased during storage, reaching 87.06, 87.0, and 87.7% after 10 days (Al-shaikh and Doosh (2018) attributed the decrease in moisture content as the storage period increased to the rate of water evaporation. The percentage of solids for the treatments increased after consolidation, as the values after manufacturing reached 10.80, 11.50, and 11.20%. The values also increased after storage, and after 10 days, they reached 10.98, 11.70, and 11.60%, respectively, for all treatments. The reason for the increase in the percentage of solids after fortification with iron compounds is the increase in the percentage of solids added and their increase after storage due to a decrease in moisture content (Al-shaikh and Doosh, 2018). Protein levels were 3.50%, 3.45%, and 3.50% after manufacturing. Increased to 3.60%, 3.55%, and 3.58% after 10 days of storage. Protein levels may have risen owing to a reduction in moisture and an increase in percentage, including protein (Hamid and Nasser, 2019). Iron did not affect fat content, with percentages of 3.70%, 3.66%, and 3.72% post-processing. After ten days, these percentages rose to 3.76%, 3.71%, and 3.77%, respectively, demonstrating that fat content stays consistent with Iron addition but varies due to humidity decrease (Al Shaikh and Doosh, 2018). After adding iron salts, ash concentration rose to 0.80%, 0.83%, and 0.84% at manufacture. These values increased during storage for all treatments to approximately, about, and around. The findings aligned with the research conducted by Zina and Nasser (2019) and El Kholy (2011) suggested that the increased ash content was attributed to the incorporation of iron salts during the consolidation process.

Table 1: Chemical composition of unfortified and iron-fortified yoghurt samples for four storage periods

Treatments	%	1 st	3th	7th	10th
T1	Moisture %	88.13a	87.98b	87.53c	87.06d
	Total solids	10.80d	10.90c	10.95b	10.98a
	Protein %	3.50b	3.58a	3.59a	3.60a
	Fat %	3.70b	3.73a	3.75a	3.76a
	Ash%	0.80a	0.82a	0.83a	0.84a
T2	Moisture %	87.87a	87.55b	87.13c	87.00d
	Total solids	11.50c	11.60b	11.60b	11.70a
	Protein %	3.45c	3.46b	3.50b	3.55a
	Fat %	3.66b	3.69a	3.70a	3.71a
	Ash%	0.83a	0.85a	0.86a	0.88a
T3	Moisture %	88.16a	87.86b	78.10c	87.7d
	Total solids	11.20d	11.30c	11.50b	11.60a

Protein % 3.50c 3.51c 3.53b 3.58a

Fat % 3.72b 3.72b 3.76a 3.77a

Ash% 0.84a 0.84a 0.85a 0.86a

*Different letters within column indicating of significant differences ($p < 0.05$)

Estimation of pH and Total titratable acidity

When held for 0, 3, 7, and 10 days, Figure (1) displays the pH, and Figure (2) the total acidity for T1, T2, and T3. At a probability threshold of $P < 0.05$, the statistical analysis revealed that the treatments differed significantly in terms of both total acidity and pH. The capacity of the starting bacteria to transform the sugar lactose into lactic acid caused a reduction in pH and a rise in acidity as the storage duration grew. The data also reveal that Iron has no impact. Also, different types of iron salts resulted in different pH and acidity levels. Instantaneous post-manufacturing pH were 4.6, 4.5, and 4.5, respectively; subsequent storage periods saw those levels drop to 3.60, 3.59, and 3.50, respectively. The findings corroborated those of (Shaghaghi et al., 2013; El-Kholy et al., 2011), which revealed that, depending on the iron salts employed for fortification, the pH and the acidity rises after storage. After 10 days of storage, the acidity levels of the samples rose to 1.236, 1.298, and 1.299%, respectively, from their initial manufacture values of 1.055, 1.065, and 1.066, according to the data. The starter bacteria break down the lactose sugar into lactic acid and other organic acids. This lowers the PKA inside the cell to 3.83, making the cell membrane more permeable to substances like lactate and acetate. As a result, the pH, and the acidity increases for longer periods of storage (Yilmas and Kurda, 2014). The acidity of the yogurt was unaffected by the addition of Iron just after manufacture. Iron salts of different types increased acidity.

Figure 1: pH of unfortified and iron-fortified yoghurt samples for four storage periods

*Different letters within column indicating of significant differences ($p < 0.05$)

Figure 2: Total titratable acidity of unfortified and iron-fortified yoghurt samples for four storage periods

*Different letters within column indicating of significant differences ($p < 0.05$)

Peroxide value

The peroxide value is an indicator of fat oxidation and, thus, product spoilage. Figure (3) shows the peroxide value for T1, T2, and T3 when stored for 0, 3, 7, and 10 days. It was observed that there were significant differences in the peroxide value at the probability level of $P < 0.05$. It was observed that The value of peroxide increased with increasing storage periods, as the values at the beginning of storage reached 1.85, 1.88, and 1.87 MeqO₂/kg for each of the treatments T1, T2, and T3, respectively, and at the end of the storage period, they increased to 2.01, 2.16, and 2.15 MeqO₂/kg, respectively. The antioxidant activity of yoghurt leads to enzymatic protein degradation, which leads to the production of peptides with the ability to inhibit food fat peroxides by seizing free radicals, inhibiting peroxides, and binding to metal ions (Singh et al. 2014). The results also show a slight increase in fat oxidation for the T2 and T3 iron-fortified samples compared to the unfortified control treatment. This is attributed to the presence of Iron, which promotes fat oxidation, the formation of free radicals, and the production of a metallic taste (Gupta, 2013). The decrease in fat oxidation in yoghurt is due to the milk's content of vitamin E and lactoferrin protein, which work to bind iron ions and also donate a hydrogen atom to free radicals, thus reducing the continued occurrence of auto-oxidation (Gjorgievski et al., 2016).

Figure 3: Peroxide value (MeqO₂/kg) for samples of unfortified and iron-fortified yoghurt for four storage periods

*Different letters within column indicating of significant differences ($p < 0.05$)

Lactic Acid Bacteria

In Table (2), we can see the lactic acid bacteria counts for T1, T2, and T3 after 0, 3, 7, and 10 days of storage. The numbers of lactic acid bacteria showed significant differences at the $P < 0.05$ level of probability. As the storage period increased, the number of bacteria also increased, reaching 45×10^6 , 50×10^6 , and 55×10^6 CFU/ml at the beginning of storage. On the other hand, it hit 75×10^6 by the time the storage period was over. Furthermore, 90×10^6 CFU/ml and 95×10^6 CFU/ml, respectively. The results also show that the effect varies according to the type of Iron used and the percentage of acidity. Lactic acid bacteria benefit from amino acids, peptides, proteins, nitrogen sources, carbohydrates, and fatty acids as a source of energy, so the proportions of components in milk products decrease after fermentation (Hussein and Isa, 2021). The growth of lactic acid bacteria increases in the yoghurt of dairy products. Fortification does not reduce these numbers, and they also increase during storage, which leads to a decrease in the number of pathogenic bacteria and the elimination of spoilage caused in foods (Naumov et al., 2020). Aquilanti et al. (2012) indicated that fortification of cheese with minerals reduces the growth of various types of bacteria, as it works to inhibit species of Lactobacillus bacteria. The positive ions Mn, Ca, Mg, and Sr work to remove cations from proteins when they bind to metals, which reduces the effect of metals. On bacteria, the pH decreases due to the interaction of components of the bacterial cell positive for the Gram stain, including lactic acid bacteria.

Table 2: Number of lactic acid bacteria for samples of unfortified and iron-fortified yoghurt for four storage periods

10th	3th	2th	1st	Treatments	
75× 106c		60 ×106b	55× 106c	45 × 106c	T1
90× 106b		75× 106b	55× 106b	50× 106b	T2
95× 106a		85× 106a	61× 106a	55× 106a	T3

*Different letters within column indicating of significant differences ($p<0.05$)

Viscosity estimation

Rheological tests are important tests to determine the properties of food materials. They are one of the main factors, in addition to flavor and appearance, that determine the extent of sensory acceptance of that food by the consumer (Dinkci et al., 2011). Indicators of yoghurt quality include viscosity, which is associated with the product's stability and flavor (Lewis, 1996). In Figure 4, we can see the viscosities of T1, T2, and T3 after 0, 3, 7, and 10 days of storage. The results showed that there were notable variations at the 0.05 level of probability. The data demonstrated that viscosity increased with increasing storage times, peaking just after production. Upon storage, they rose to 2800, 2890, and 2879 cP, respectively. Following 10 days, they reached 2900, 2950, and 2940 cP. The decrease in pH and increase in acidity cause yoghurt's viscosity to rise after storage. (Walstra et al., 2005). Figure 2 shows that compared to the control sample T1, the viscosity of the Iron-fortified T2 and T3 samples was higher. This finding suggests that the addition of minerals, such as Iron, increases the product's viscosity because of the high proportion of extra solids. According to (Jasim and Saadi, 2020), this is because Iron may bind casein molecules, which improves the viscosity and increases the strength of the bonds. Because the yoghurt gel matrix is sensitive to changes in the ionic binding strength of the salt molecules used for reinforcing, the viscosity of the gel varies with the kind of salts applied (De and Nayak, 2022).

Figure 4: Viscosity values for unreinforced and iron-reinforced yoghurt samples for four storage periods

*Different letters within column indicating of significant differences ($p<0.05$)

Hardness

Figure (5) indicates the hardness values of treatments T1, T2, and T3 when stored for 0, 3, 7, and 10 days. It was noted that no significant differences appeared between the treatments at the probability level of $P<0.05$. The results showed an increase in hardness with increasing storage periods, and it reached the beginning of

storage at 98.70, 99.80, and 99.70 g. It increased after storage, and after 10 days of storage, it reached 100.10, 101.10, and 00.601 g. The percentages varied depending on the type of iron compound used. Adding Iron of both types, T2 ferrous sulfate and T3 ferrous bisglycinate, led to an increase in the hardness property of the yoghurt. Compared with the control sample T1, the reason for the increase in hardness in the product after fortification with Iron is due to its ability to form bridges between casein molecules and coagulate them, thus increasing the bonding forces between the molecules and increasing the cohesion within the protein bar, which increases the hardness (Qureshi and Hassan, 2011). A difference in hardness was observed. Depending on the type of salts added, the values of the T2 and T3 parameters varied as a result of the difference in the ionic strengths of the salts used, which affected the yoghurt gel (Jasim and Saadi, 2020). The reason for the decrease in elasticity after storage is attributed to increased proteolysis or decreased moisture content, which reduces its elasticity (Korish and Abeer, 2012). Liu et al., (2015) attributed the reason for the high hardness during storage to the low humidity upon evaporation, and the high hardness in the samples reinforced with minerals compared to the control samples is due to the high percentage of solids, and this is directly proportional to the cohesion of the samples. Patrignani et al., (2006) indicated that the hardness standard in yoghurt is closely related to solids and protein content, as the hardness increases with their increase.

Figure 5: Hardness values for unreinforced and iron-reinforced yoghurt samples for four storage periods

*Different letters within column indicating of significant differences ($p < 0.05$)

Whey separation

The most crucial indicator of yoghurt quality during storage is spontaneous whey separation (Shakerian et al., 2015). When particles are absent, heat treatment is inadequate, or the pH is less than 4.4, leaching occurs (Konhorst, 2007). Table 6 shows the predicted values of spontaneous whey exudation after 0, 3, 7, and 10 days in storage for treatments T1, T2, and T3. At a probability threshold of $P < 0.05$, it was observed that the treatments were not significantly different from one another. As the testing durations increased, whey exudation increased as well. Storage: It was observed that the yoghurt supplemented with ferrous sulfate outperformed the rest of the treatments, as the values for the treatments reached 5.5, 6.8, and 6.4%, respectively, and the values increased after storage, reaching 7.9, 8.9, and 8.5% after 10 days. This is due to the increase in whey purity. Extended storage leads to an increase in total acidity and a decrease in pH values (Panesar and Shinde, 2011).

Figure 6: Whey whey separation of unfortified and iron-fortified yoghurt samples for four storage periods

*Different letters within column indicating of significant differences ($p < 0.05$)

Iron content

Table 7 illustrates the predicted iron concentrations after 0, 3, 7, and 10 days of storage for treatments T1, T2, and T3. There were notable differences between the treatments, with a probability threshold of $P < 0.05$. The findings demonstrated that the treatments significantly raised the iron content. In the zero storage period, T2 and T3 were 0.61 and 0.80 mg/kg, respectively, whereas T1, the control sample, was 0.039 mg/kg. Over the course of the storage periods, the iron content dropped dramatically; on the tenth day, it was at its lowest, amounting to 0.026, 0.50, and 0.68 mg./kg for each treatment. Results showed that ferrous sulfate-fortified samples outperformed all other treatments. Debasmitta and Binata Nayak (2017) indicated that the samples of yoghurt fortified with Iron are nutritionally rich and acceptable, and they are also a suitable way to enhance Iron in food, as noted. The amount of Iron in the yoghurt increases, and its quantity decreases as the storage period increases.

Figure 7: Iron quantity for unfortified and iron-fortified yoghurt samples for four storage periods

*Different letters within column indicating of significant differences ($p < 0.05$)

Sensory evaluation

Ten food experts from the College of Agriculture's Department of Food Sciences documented their sensory assessment findings for treatments T1, T2, and T3 after 0, 3, 7, and 10 days of storage in Table 3. The features of color, texture, flavor, and overall acceptance did not show any significant variations between the treatments after fortification at the probability threshold of $P < 0.05$ within the one storage period. However, significant differences were found between different storage periods. T1 performed very well, earning a score of 85.9, while treatments T2 and T3 achieved scores of 85.0 and 85.2, respectively. T1 also recorded the best sensory characteristics compared to treatments T2 and T3. In terms of general acceptance, it reached 22.7, 22.3, and 22.5, respectively, and both treatments, T1 and T2, received the highest rating for taste and flavor, 17.8. Treatment T3 also obtained the highest score in terms of texture, 31.5, as fortification with Iron in small percentages did not affect the general acceptance of the yoghurt product. Consumers place more stock in sensory quality indicators when evaluating dairy products than in their chemical makeup, which loses value with time owing to storage and expiry, producing color and taste changes caused by excessive acidity (Naumova et al., 2020). According to Kahraman and Ustuno (2012) the hardness increases after reinforcement with metals like Iron since strength is related to the quantity of additional metals.

Table 3: Sensory evaluation of raw and fortified milk samples for four storage periods

Treatments	Storage periods/day	Color/20	Textur/35	Flavor/20	general	acceptability/25
	Total /100					
T1	0	15.2a	30.2a	17.8a	22.7a	85.9a
	3	14.5a	30.0a	16.7a	20.5b	81.7b

	7	12.8b	30.0a	16.5a	19.3b	78.6c
	10	10.9c	29.5a	17.6a	19.3b	77.3d
T2	0	14.8a	30.1a	17.8a	22.3a	85.0a
	3	14.0a	30.2a	16.3a	20.5b	81.0b
	7	13.1b	30.0a	14.2b	19.2b	76.5c
	10	10.5c	27.5b	14.0b	19.1b	71.1d
T3	0	15.0a	31.5a	16.2a	22.5a	85.2a
	3	15.5a	30.0a	15.2a	19.5b	80.2b
	7	13.8b	30.1a	15.0a	18.2b	77.1c
	10	11.0c	30.2a	15.0a	18.1b	74.8d

*Different letters within column indicating of significant differences ($p < 0.05$)

CONCLUSION

The research found that adding healthful iron components to yoghurt altered its acidity, pH, and chemical makeup little. Because Iron is associated with fat oxidation, its fortification led to an increase in the peroxide value. Since iron fortification did not result in a reduction in the populations of lactic acid bacteria, its effects on their development were mixed. Different types of iron compounds utilized for reinforcing had different effects on the material's viscosity, hardness, and whey separation, although all three showed improvement. Because there was no discernible difference in the fortified product's sensory quality indicators, it is possible to fortify dairy products with Iron to make up for the mineral's lack in whole foods and provide them with additional health benefits, which is particularly helpful for vegetarians and vegans who eat dairy products.

REFERENCES

- Al-Shaikh, S.A.H. and Doosh, K.S.H. (2018). Study the effect of fortifying with selenium or physiochemical and sensory properties of the functional yoghurt process. *Karbala Journal of Agricultural Sciences*. 5(2).
- Aquilanti, L., Kahraman, O., Zannini, E., Osimani, A., Silvestri, G., Ciarrocchi, F., ... & Clementi, F. (2012). Response of lactic acid bacteria to milk fortification with dietary zinc salts. *International Dairy Journal*, 25(1): 52-59
- Arnoldi, A. (2001). Thermal processing and food quality: analysis and control. *Thermal Technologies in Food Processing*: 138-159.

- Association of Official Analytical Chemists A.O.A.C. (2008). Official Methods of Analysis 16th ed. Association of Official Analytical Chemists International Arlington, Virginia, U.S.A.
- Coroian, A., Raducu, C., Miresan, V., Cocan, D., Balta, I., Longodor, A. L. & Marchiis, Z. (2019). Physico-chemical composition and antioxidant capacity of buffalo milk. Scientific Bulletin. Series F. Biotechnologies, 23: 2285-1364.
- Dave, R.I . and Shah, N.P. (1996). Evaluation of media for selective enumeration of *Streptococcus thermophilus*, *Lactobacillus delbrueckii* ssp. *bulgaricus*, *Lactobacillus acidophilus*, and *bifidobacteria*. Journal of Dairy Science, 79(9): 1529-1536.
- Debasmita De, Binata Nayak (2022). Evaluation of physico-chemical properties of Iron-fortified yoghurt, International Journal of Food Science and Nutrition. 7(1) : 12-15.
- Debasmita De1, Dr. Binata Nayak (2017). Evaluation of Storage Capacity of Iron Fortified Yoghurt by Physico-chemical, Chemical and Microbiological Analysis. International Journal of Environment, Agriculture and Biotechnology (I.J.E.A.B.) .2(1).
- Dinkci, N.; Kesenkas, H.; Seckin, A.K.; Kinik, O. and Gonc, S. (2011). Influence of a vegetable fat blend on the texture, microstructure, and sensory properties of kosher cheese. Grasas Y. Aceites, 62: 275-283.
- El-Kholy AM, Osman M, Gouda A, Ghareeb WA (2011). Fortification of yoghurt with Iron. World Journal of Dairy and Food Science 6:159-165.
- Gjorgievski, N. ; Tomovska, J. ; Dimitrovska, G. Makarijoski, B. and Shariati, M. (2016). Determination of the antioxidant activity in yoghurt . J. Hygienic Eng. and design, 15(2): 88 – 92.
- Guo, Q.; Sun, D.; Cheng, J.; Han, Z. (2.17) Microwave processing techniques and their recent applications in the food industry. Trends in Food Science & Technology. 67: 236-247.
- Gupta, C. 2013. Development and evaluation of microencapsulated iron-fortified yoghurt. (Doctoral dissertation, NDRI, Karnal).
- Horwitz, W. and Catimer, G. (2005). Official Methods of Analysis of A.O.A.C. International. 18th ed., A.O.A.C. International. U.A.S. Chapter 50: 15-20.
- Hussein, T. A., & Isa, J. K. (2021). Study of the microbiological quality and physiochemical properties of the soft white cheese traditionally produced in Wasit Province in Iraq. NVEO-NATURAL VOLATILES & ESSENTIAL OILS Journal| N.V.E.O.: 48-61.
- Jasim, A. A., & Al-Saadi, J. M. (2020). Study the effect of adding iron salts on the physiochemical and sensory properties of yoghurt. Indian Journal of Forensic Medicine & Toxicology, 14(4): 2771-2778.

-Jayalalitha, V., Elango, A., & Pugazhenth, T.R. (2022). Iron Fortification in Yoghurt: Methods and Processes, as well as their Influence on Physico-chemical and Sensory Qualities. *International Journal of Agriculture, Environ.*

-Jurado-Guerra, J. A., Flores-Mancha, M. A., Juárez-Moya, J., Lechuga-Valles, R., Rentería-Monterrubio, A. L., Sánchez-Vega, R., ... & Chávez-Martínez, A. (2023). Physicochemical and Rheological Characteristics of Stirred Yoghurt Fortified with Vitamin B12 and Melatonin. *Journal of Food Processing and Preservation*, 2023.

-Kahraman, O., & Ustunol, Z. (2012). Effect of zinc fortification on Cheddar cheese quality. *Journal of Dairy Science*, 95(6): 2840-2847.

-Kamal, R.M.; Alnakip, M.E.; Abd El Aal, S.F.; Bayoumi, M.A. (2018). Bio-the controlling capability of probiotic strain *Lactobacillus rhamnosus* against some common foodborne pathogens in yoghurt. *Int. Dairy J*, 85: 1-7.

-Konhorst, A. (2007). *The Technology of Dairy Products*. Food Science and Technology. U.S.A.

-Korish, M. and Abeer, A. (2012). Improving the textural properties of Egyptian kariesh cheese by the addition of hydrocolloids. *International Journal of Dairy Technology*. 65 (2).

-Lewis, M. J. (1996). *Physical properties of food and food processing systems*. Cambridge: Wood Head Publishing Limited.

-Li, Y.; Wu, Y.; Quan, W., Jia, X.; He, Z.; Wang, Z.; ... Zeng, M. (2021). Quantitation of furosine, furfurals, and advanced glycation end products in milk treated with pasteurization and sterilization methods applicable in China. *Food Research International*. 140: 110088.

-Liptak, B. G., & Lipták, B. G. (2003). *Process measurement and analysis* (Vol. 20). Boca Raton, FL, U.S.A.: C.R.C. press. Papadopoulou, O. S., Argyri, A. A., Kounani, V., Tassou, C. C., & Chorianopoulos, N. (2021). The use of Fourier transforms infrared spectroscopy to monitor the shelf life and safety of yoghurts supplemented with a *Lactobacillus plantarum* strain with probiotic potential. *Frontiers in Microbiology*: 1625.

-Liu, H. Y., Zhu, W. Z., Lu, B. Y., Wei, Z. H., & Ren, D. X. (2015). Effect of feed selenium supplementation on milk selenium distribution and mozzarella quality. *Journal of Dairy Science*, 98(12): 8359-8367.

-Moineau-Jean, A.; Champagne, C.P.; Roy, D.; Raymond, Y.; LaPointe, G. (2019). Effect of Greek-style yoghurt manufacturing processes on starter and probiotic bacteria populations during storage. *Int. Dairy J.*, 93: 35-44.

-Naumova, N., Burmistrova, O., & Burmistrov, E. (2020). Influence of enriching additives on farmer's cheese formation and its functional properties. *Songklanakarin Journal of Science & Technology*, 42(2).

- Panesar, P. S. and Shinde, C. (2011). Effect of Storage on syneresis, pH, Lactobacillus acidophilus count, Bifidobacterium bifidum count of Aloe- vera fortified probiotic yoghurt .current Res. in dairy Sci., 12(2): 1 – 7.
- Patrignani, F. R. Lanciotti, J.M. Mathara, M.E. Guerzoni, W.H. Holzapfel,(2006) "Potential of functional strains, isolated from traditional Maasai milk, as starters for the production of fermented milk," International Journal of Food Microbiology,.107(1): pp. 1-11.
- Preedy VR, Srirajaskanthan R, Patel VB.(2013). Handbook of food fortification and health. Humana Press, New York.
- Qureshi, A. M., Hassan, S. Y., Sulariya, A. M., & Rashid, A. A. (2011). Preparation and nutritional evaluation of garlic-based yoghurt. Science International, 23(1).
- S'wia, der, K.; Kulawiak, M.; Chen, Y. (2020), Types of lactose–free products and their availability on the Polish market. Types of lactose–free products and their availability on the Polish market. Postępy Tech. Przetw. Spoż. 1: 39–45.
- Schmuller, J. (2017). Statistical Analysis with R For Dummies. John Wiley and Sons.111, River Street, Hoboken, Canada. 438p.
- Shaghaghi,M.,Pourahmad,R.,& Adeli,H.M.(2013).Synbiotic yoghurt production is achieved using prebiotic compounds and probiotic lactobacilli. International Research Journal of Applied and Basic Sciences,5(7): 839-846.
- Shakerian M., Razavi S.H., Ziai S.A., Khodaiyan F., Yarmand M.S., Moayedi A.(2015) Proteolytic and ACE-inhibitory activities of probiotic yoghurt containing non-viable bacteria as affected by different levels of fat, inulin and starter culture. J. Food Sci. Technol.;52(4):2428–2433.
- Singh, B. P. ; Vij, S. and Hati, S. (2014). Functional Significance of bioactive peptides derived from soybean. J. Homopage, 54: 71 – 179.
- Soad, H. T., Mehriz, A. M. and Hanafy, M. A.(2014). Quality characteristics of ice milk prepared with combined stabilizers and emulsifier blends. International Food Research Journal,21(4): 1609-1613.
- Wajs, J., Brodziak, A., & Król, J. (2023). Shaping the Physicochemical, Functional, Microbiological, and Sensory Properties of Yoghurts Using Plant Additives. Foods, 12(6): 1275.
- Walstra, P., Walstra, P., Wouters, J. T., & Geurts, T. J. (2005). Dairy science and technology. C.R.C. press.
- Yilmaz-Ersan, L. and E, Kurdal.2014.The production of set-type-bio-yogurt with commercial Probiotic culture. Int. J.Chem. Eng. and Appl.5:402-408.

سی امین کنگره ملی و پنجمین کنگره بین المللی علوم و صنایع غذایی ایران

The **30th** National and the **5th** International
Iranian Food Sciences and Technology Congress

● October 2024, Tehran

● ۲۵ و ۲۶ مهرماه ۱۴۰۳، تهران ●



-Ziena, H and Nasser, S.A. (2019) Iron Fortified Yoghurt: Effect of Different Iron Salts on the Properties of Yoghurt. Adv Dairy Res 7:223.