# STUDY OF THE PHYSOCHEMICAL, RHEOLOGICAL AND SENSORY PROPERTIES OF YOGHURT FORTIFIED WITH MICROENCAPSULATION IRON

**I. H. Sadiq** **K. S. Doosh**
**Researcher** **Prof.**
**Dept. Food Science –Coll. of Agric., University of Baghdad**
**israa0934@gmail.com** **oum_zain@yahoo.com**

**ABSTRACT**

**This study was aimed to determine the effect of milk fortification with encapsulated and non-encapsulated iron on the physiochemical, rheological and sensory properties of the functional yoghurt. Different concentrations of capsulated ferrous sulphate 5, 7.5, 15 mg / 100ml milk were used and represented as T2,T3 and T4 treatments respectively, as well as the treatment with non-encapsulated iron 15 mg / 100 ml as T1 and control treatment (C) in which yoghurt was made from whole milk without iron addition. The physiochemical, rheological and sensory properties of the products were tested during storage period at a temperature ( 5 ± 1) ° C. The results revealed that there was no significant differences ($p<0.05$) between control and other treatments in moisture, protein, fat carbohydrate, ash content. In addition, the fortified yoghurt samples were showed low ADV and PV values and better sensory and rheological properties.**

**Key words: ADV, PV, sensory evaluation,**
**Part of M.Sc. thesis of the 1st author.**



## دراسة الخصائص الفيزوكيميائية والريولوجية والحسية لليوغرت المدعم بالحديد المغلف

اسراء حيدر صادق كفاح سعيد دوش
الباحث استاذ
قسم علوم الاغذية – كلية الزراعة – جامعة بغداد

**المستخلص**

هدفت الدراسة الى تحديد تأثير التدعيم بالحديد المغلف وغير المغلف على الخصائص الفيزيوكيميائية والحسية لليوغرت الوظيفي وذلك بتدعيم الحليب الخام بتراكيز مختلفة من ملح كبريتات الحديدوز وهي 5 , 7.5 , 15 ملغم 100/ مل والمتمثلة بالمعاملات T2 و T3 و T4 على التوالي فضلا عن معاملة اليوغرت المدعم بالحديد غير المغلف بتركيز 15 ملغم / 100 مل معاملة T1 ومعاملة السيطرة C التي صنع فيها اليوغرت من حليب غير مدعم بالحديد .أجريت الفحوصات الكيميائية و الفيزيائية و الريولوجية بالأضافة الى التقويم الحسي بعد التصنيع مباشرة وعند الخزن في درجة حرارة (5±1)م° لمدة 21 يوما . أوضحت النتائج الى عدم وجود فروق معنوية في قيم الرطوبة والدهن والبروتين والكاربوهيدرات والرماد بين معاملة السيطرة والمعاملات الاخرى كما تميزت معاملات اليوغرت المدعمة بالحديد المغلف باقل قيم ADV وPV وتميزت معاملات الحديد المغلف بتحسين الخصائص الحسية والصفات الريولوجية لليوغرت.

الكلمات الافتتاحية: درجة حموضة الدهن، الرقم البيروكيدي,التقويم الحسي.
البحث جزء من رسالة الماجستير للباحث الاول .

*Received:23/4/2019, Accepted:5/7/2019

## INTRODUCTION

International Life Science Institute (ILSI) describes functional foods as foods that have convincing evidence that they have a beneficial and healthy effect on one or more body functions, unlike conventional foods (23) Japanese, European and American markets are among the most popular markets for functional foods. There is a special food approval system known as FOSHU (Food for Specific Health Uses). The most popular functional foods are processed dairy products, meat products and other fermented foods. The aim of the use is to reduce the risk of chronic diseases such as high blood pressure, cholesterol, atherosclerosis and heart disease as well as stimulate the immune system (29). Iron containing foods are among the functional foods because they have beneficial health effects, especially the treatment of anemia, mainly foods containing iron with high bioavailability (22). Iron is the most stable chemical element and is essential for human and animal life. People with good nutrition typically have 4 to 5 grams of iron in their bodies it enters as a vital element in the synthesis of many organic compounds and enzymes in all living organisms (35). According to statistics, 3.5 million people in both industrialized and developing countries suffer from malnutrition and 52% of pregnant women are at risk of anemia. Precise microencapsulation is defined as a technology for filling solid, liquid or gaseous substances in controlled small capsules whose contents are released under specific conditions , the importance of careful microencapsulation of the biological components to their sensitivity under the influence of many different conditions and not to lose and maintain them at different processes of manufactured like heating and cooling as well as acidic conditions, antioxidants, oxygen and other factors that harm the base material (9). The yoghurt is one of the most widely distributed dairy products in the world and is widely consumed so it is popular food , the yoghurt may be a modern food, but it has ancient origins. Although its original habitat is not established, it is considered one of the oldest fermented dairy products known to humans. It is believed to be native to the Middle East and has been in existence for thousands of years since the presence of cattle, sheep and goats (11). The US Food and Drug Administration (FDA) has defined the yoghurt as a food produced by Streptococcus *Salivarius* Subspp *thermophiles* and *Lactobacillus delbruecii* subspp *bulgaricus*, which is incorporated into one or more of the following dairy ingredients: whole or whole cream and milk, as well as one or more other substances choose it like vitamins and mineral salts (10) The current study aimed to produce yoghurt from whole raw milk fortified with four different concentrates of encapsulated and non-encapsulated iron and study the physiochemical. rheological and sensory properties.

## MATERIALS AND METHODS

### Source of milk and iron capsules

whole cow's milk was obtained from the dairy factory of Department of Food Science _ Collage of Agricultural Engineering Sciences at University of Baghdad. The powder milk which used to modify the percentage of total solids in experimental yoghurt was obtained from the local markets in Baghdad and was a regale french brand, Iron which used in encapsulated and non-encapsulated was ferrous sulphate. The iron is encapsulated by cold spraying material using sodium alginate.

### Process of microencapsulation

Procedure was conducted according to the method (19).

1-Prepared the encapsulated by cold spraying material using 2g to sodium alginate to 100 ml distilled water. 2-Mix the content in magnetic stirrer for 30 minutes (100rp). 3-Mix for 15 minutes using a shaker incubator. 4-Add ferrous sulphate and ascorbic acid and mix for 15 minutes at 100rpm. 5-Spray CaCL2. 6-Keep the microencapsulated in refrigerator for 4-3 hour for solidification. 7-Wash the microcapsules by distilled water to remove $CaCL_2$. 8-Microencapsulated was kept in a freeze at-20°C and lyophilized

### Functional yoghurt manufacturing

Function yoghurt was manufactured according to the method described by (18) A certain amount of bovine milk was divided into five parts. The first part was left without any treatment and used in a manufacturing control treatment (C). The second was fortified with

non-encapsulated iron at a concentration of 15 mg / 100 ml with 5 mg of ascorbic acid (T1). The third, fourth and fifth were fortified with encapsulated iron with the a following ratios of 5, 7.5 and 15 mg / 100 ml with 5 mg ascorbic acid T2, T3, T4. All treatments heated to 90 ° C for 10 minutes and then milk was cooled to 42 ° C, starter culture (*Streptococcus salivarius* subsp *thermophile* sand *Lactobacillus delbruecki* ssp *bulgaricus*), was added in amounts of 3% packed in plastic containers of 150 ml and incubated at 42 ± 1 ° C until full coagulation (3.5 hours) when pH reached to 4.6, and then all samples was taken out of the incubator and transferred to the refrigerator for cooling and storage at (5±1) ° C. The necessary tests were done at 1, 3, 7, 14 and 21 days of manufacturing.

**Physicochemical tests for iron-encapsulated and non-encapsulated yoghurts**

The percentage of moisture content, was estimated according to (5). Total nitrogen and non-protein nitrogen were determined according the method mentioned in (21).The fat percentage was estimated by Babcock method (21). while Carbohydrates calculated theoretically by difference (16). The total acidity and pH value was estimated according to (6).

**Determination of acid degree value (ADV) and peroxide value (PV)**

The value of Acid Degree was estimated as in method (12) as well as Peroxide value was estimated by method in (6)

**Determination of viscosity**

The apparent viscosity of yoghurt samples was estimated after 1, 3, 7, 14 and 21 days of storage at a temperature (5±1) ° C according to (13) using a device Mry-VR3000 viscometer (supplier of Engineering Lab Inc., stoughton, Mass)..

**Water holding capacity**

Water holding capacity was estimated by Parnell-Clunies method (27). Ten g of yoghurt sample centrifuged at 3000 g for 60 min at 10 ° C. The supernatant was then removed and the residual weight was recorded, the WHC was calculated according to the following equation:

Water holding capacity %

$$\frac{\textbf{the weight of the precipitate}}{\textbf{the original weight of the sample}} \times \mathbf{100}$$

**Spontaneous Whey Separation**

Spontaneous Whey Separation was estimated by placing 50 mL of yoghurt in bowl angle at 45 ° for two hours at 5 ° C, then supernatant was removed by using the syringe .The precipitate was reweighed within 10 seconds to avoid excessive whey separation (4).

**Sensory Evaluation of Yoghurt**

The sensory evaluation tests of the yoghurt samples were conducted in the Department of Food Science, Faculty of Agricultural Engineering Sciences, University of Baghdad, by a number of specialist professors according to the sensory evaluation format which included the characteristics of flavor, texture, color and appearance (26).

**Statistical analysis**

SAS (2012) program was adapted on–LSD to compared between control treatment and other treatment (31).

## RESULTS AND DISCUSSION

**Chemical Composition of yoghurt**

Table 1 reveal the percentages of moisture for experimental yoghurt samples during the storage period (1-21days) at 5±1 ° C. It has been noticed that there were no significant difference between moisture content for control treatment and the fortified yoghurt at the first day of manufacturing. These values were 87.02% for treatment (C) and was 86.79, 87.04, 86.85 and 86.83% for T1,T2,T3,T4 respectively. While after 21 days storage these values reached to 86.62% for (C) and 86.48, 86.65, 86.59 and 86.62% respectively. This could be due to the evaporation of moisture content of the samples during the storage period. These findings were in consistent with those reported by (28) who showed a decrease in yoghurt moisture content from 84.78 to 84.65% during cold storage. The obtained result was also close to result found by (7) which was 87.22%. The results of the statistical analysis indicate that there were no significant difference ($P < 0.05$) in the percentage of moisture between C treatment and the other treatments at the end of the storage period 21 days.

**Protein**

Table 1 illustrate the percentages of protein in experimental yoghurt treatments C, T1, T2, T3, and T4 directly after manufacturing and during storage period. It was for C treatment

4.21% and for T2 4.21% and 4.22% for the treatments (T1,T2,T3,T4) . For all yoghurt treatments the percentage of protein were increased through the storage period. This was on line with (28) finding who stated that the moisture content of yoghurt increased from 4.89 to 4.92% during 12 days storage. This could be attributed to the decrease in moisture that led to an increase in the percentage of total solids including protein. The results of the statistical analysis was indicated no significant difference (P <0.05) in the percentage of protein between the treatment C and other treatments after manufacturing and during storage period 21 days at (5±1) ° C.

**Fat**

Table 1 shows the percentage of fat in the studied yoghurt samples. The fat content of control sample was 3.50% and for the T1,T2,T3,T4 were 3.51, 3.50, 3,50 and 3.50% respectively after the manufacturing process these results were close to that found by (32), who found that the fat value was 3.67% for yoghurt manufactured from whole milk. While the percentage of fat for other treatments was 3.51% and 3.50% . These values increased to 3.82% for (C) and 3.85, 3.83, 3.81 and 3.81% for T1, T2, T3 and T4 respectively during of storage period (21 days) with no significant difference. The values after 21 days for C were 3.82% and for T1, T2, T3 and T4 were 3.85, 3.83, 3.81 and 3.81%, respectively. The increasing in fat content was. due to decrease in moisture content through the storage period.

**Carbohydrates**: Table 1 shows the percentage of carbohydrates for the experimental treatments. For treatment (C) directly after manufacturing the carbohydrate content was 4.58%. This result was close to that found by (32) who reported that was 4.47%. The carbohydrate content of yoghurt samples (T1,T2,T3 and T4) were 5.15, 4.57, 4.74 and 4.76% respectively immediately after manufacturing. while after 21 days, the percentage of carbohydrates in all yoghurt treatments were decreased (for treatment C was 4.26%, while for T1 , T2 ,T3 and T4 were 4.27, 4.2, 4.29 and 4.23% respectively). This decrease may be due to the activity of the starter bacteria that convert lactose to lactic acid. This result are comparable to the result found by (37) who indicated that the carbohydrates content for yoghurt decreased from 4.42% to 4.07% during 25 days of storage period. The statistical analysis showed no significant differences (P <0.05) between C treatment and all other treatments after manufacturing process and during the 21day storage at (5±1) ° C.

**Ash**

Table 1 indicates the percentage of ash in the experimental yoghurt samples, after processing for C treatment was 0.69%. This result was consistence with that was found by (34) who stated that, the ash content for yoghurt manufactured from whole milk was 0.70%. while the percentage of ash for T1,T2,T3 and T4 were 0.70, 0.68, 0.69 and 0.69 % respectively. By the end of storage period those values became for C treatment was

**Table 1.Chemical composition of plain yoghurt (Control) and for non-encapsulated and encapsulated iron fortified yoghurt during storage period (21 days) at (5±1) ° C**

| Treatment | Storage period (day) | Moisture % | Protein % | Fat % | carbohydrate % | Ash % | NPN |
|---|---|---|---|---|---|---|---|
| control C | 1 | 87.02 | 4.21 | 3.50 | 4.58 | 0.69 | 0.0232 |
| | 3 | 86.95 | 4.24 | 3.53 | 4.57 | 0.71 | 0.0240 |
| | 7 | 86.81 | 4.30 | 3.68 | 4.45 | 0.76 | 0.0258 |
| | 14 | 86.75 | 4.40 | 3.77 | 4.28 | 0.80 | 0.0269 |
| | 21 | 86.62 | 4.44 | 3.82 | 4.26 | 0.86 | 0.0275 |
| T1 | 1 | 86.79 | 4.22 | 3.51 | 5.15 | 0.70 | 0.0230 |
| | 3 | 86.62 | 4.27 | 3.56 | 4.8 | 0.75 | 0.0238 |
| | 7 | 86.58 | 4.31 | 3.67 | 4.65 | 0.79 | 0.0257 |
| | 14 | 86.51 | 4.41 | 3.79 | 4.42 | 0.87 | 0.0268 |
| | 21 | 86.48 | 4.45 | 3.85 | 4.27 | 0.95 | 0.0272 |
| T2 | 1 | 87.04 | 4.21 | 3.50 | 4.57 | 0.69 | 0.0231 |
| | 3 | 86.98 | 4.26 | 3.56 | 4.48 | 0.72 | 0.0236 |
| | 7 | 86.85 | 4.30 | 3.64 | 4.47 | 0.74 | 0.0259 |
| | 14 | 86.77 | 4.41 | 3.78 | 4.26 | 0.78 | 0.0267 |
| | 21 | 86.65 | 4.45 | 3.83 | 4.2 | 0.87 | 0.0271 |
| T3 | 1 | 86.85 | 4.22 | 3.50 | 4.74 | 0.69 | 0.0228 |
| | 3 | 86.73 | 4.26 | 3.59 | 4.71 | 0.71 | 0.0238 |
| | 7 | 86.69 | 4.31 | 3.65 | 4.62 | 0.73 | 0.0260 |
| | 14 | 86.64 | 4.41 | 3.76 | 4.4 | 0.79 | 0.0268 |
| | 21 | 86.59 | 4.43 | 3.81 | 4.29 | 0.88 | 0.0270 |
| T4 | 1 | 86.83 | 4.22 | 3.50 | 4.76 | 0.69 | 0.0229 |
| | 3 | 86.79 | 4.25 | 3.58 | 4.66 | 0.72 | 0.0240 |
| | 7 | 86.74 | 4.32 | 3.66 | 4.52 | 0.76 | 0.0260 |
| | 14 | 86.69 | 4.42 | 3.75 | 4.34 | 0.80 | 0.0269 |
| LSD value | 21 | 86.62 | 4.45 | 3.81 | 4.23 | 0.89 | 0.0271 |
| | -- | 3.05NS | 0.722NS | 0.592NS | 0.725NS | 0.316NS | 0.0093NS |

**NS (non-significant)**

0.86% and for T1,T2,T3 and T4 0.95, 0.87, 0.88 and 0.89%, respectively. The results of the statistical analysis indicate, there was no significant differences (P <0.05) in the percentage of ash between C treatment and all others treatments.

**Non protein nitrogen NPN**

The percentage of NPN in experimental treatments (C,T1,T2,T3,T4) are listed in Table 1. It has been observed that the NPN percentages after manufacturing process were 0.0232% for treatment C, and 0.0230, 0.0231, 0.0228 and 0.0229% for T1, T2, T3 and T4 respectively. These values were increased with non-significant differences during the storage period (21 days). By the end of storage period the NPN percentage reached to 0.0275% for C treatment and 0.0272, 0.0271, 0.0270 and 0.0271% for T1, T2, T3 respectively. This may be due to the function of protease enzymes produced by starter and psychrophilic bacteria (24).The statistical analysis showed no significant differences (P <0.05) between the treatment C and the rest treatments after 21 days of storage.

**Acid degree value**

Table 2 reveals the result of degree of fat hydrolysis, expressed as acid degree value for yoghurt treatments under study. The values immediately after manufacturing process for treatment C was 0.42 meq / 100 g and for T1, T2 , T3 and T4 0.43, 0.41, 0.40 and 0.42 meq \ 100 g fat, respectively. After 21 days storage these values increased to 0.86, 0.87 and 0.84 meq / 100g lipid for T2,T3,T4 respectively. The statistical analysis results indicated no significant differences (P <0.05) between treatment C and other treatments immediately after manufacturing .The results also show a gradual increase in ADV values for all treatments after 21 days. Those values became for C treatment 0.85 meq / 100g fat and for the T1 1.20 meq / 100g fat, This treatment was rejected according to the scale of BDI method .This could be due to presence of free iron, used for fortification in form of non-encapsulated, which enhance lipid oxidation

and promote activity of lipase that responsible for fat deterioration (24). ADV for T2, T3 and T4 were 0.86,0.87 and 0.84 meq / 100 g lipid respectively.

**Peroxide value**

Peroxide value is considered as an indicator for lipid oxidation, Fat oxidation damages, food products with an undesirable taste and changes in the nature and strength of the product in a way that leads to deterioration of the product. From the results in Table 2 the values of the peroxide value after manufacturing for treatment C was 0.33 meq / kg and for T1 , T2 ,T3 and T4 0.33 meq / kg respectively, and all values were in acceptable range. The results of statistical analysis indicated that there was no significant differences in the PV values between C and other treatments after manufacturing directly. While by the end of storage period, the PV increased to reach for the treatment C T0 0.73 meq / kg, while for the non-encapsulated iron fortified yoghurt treatment (T1) was 1.45 meq / kg. This was a significant development in PV within the rejected limits, while the PV for T2,T3 and T4 were 0.76, 0.75 and 0.74 meq / kg respectively. All these values are within acceptable level compared to the non-encapsulated (T1) which was over the acceptable level according to the (17). (Not higher than 1.3 meq / kg). The reason for this increasing in PV attributed to the presence of iron which promotes fat oxidation and formation of free radicals as well as production of mineral taste (14). The results of the statistical analysis showed significant differences between treatment C and T1 during 21 days of storage period.

**pH**

As it is demonstrated in Table 3,. the pH value immediately after manufacturing. for C treatment was 4.68 this is consistent with what was found by (33) who stated the pH values was 4.64 for yoghurt samples. while the pH values for T1, T2, T3 and T4 was 4.67, 4.65, 4.65 and 4.66 respectively. The pH values for all treatments were decreased after (21 days) storage , for treatment C became 4.48 and for T1,T2,T3 and T4 were 4.45, 4.46, 4.48 and 4.46 respectively. This decreasing due to the activity of the starter bacteria during storage. These results was consistent with that was found by (3). The results of statistical analysis showed that there was no significant difference ($P < 0.05$) in pH values between C treatment and others treatments after manufacturing process and during the storage period.

**Total titratable acidity**

The results of total acidity TA (calculated as % lactic acid) for the studied treatments are shown in table 3. Immediately after manufacturing. TA value for treatment C was 0.85%. This result is consistent with Nawar finding (25), who stated the TA for yoghurt was 0.80%. The TA values for T1 and T4 treatments was 0.85 and for T2 and T3 treatment was 0.84%. It has been noticed the fortification with iron had no effect on TA values as compared with control treatment. After 21 days, the TA ranged from 0.98 to 0.99 for experimental treatments, and this was in consistent with Shaghaghi result (33) who noticed an increase in TA from 0.78% at the first day to 0.92% at the end of storage period (28 day). The results of the statistical analysis showed that there was no significant difference ($P < 0.05$) in the TA values between control treatment and all other treatment immediately after manufacturing and during the 21day of storage period.

**Table 2. Changes in acid degree value ADV and peroxide value PV for control treatment. Non-encapsulated and iron-encapsulated treatments with different concentrations immediately after manufacturing and during storage periods at (5 ± 1) ° C for 21 days**

| Treatment | Storage period (day) | Acid degree value ADV(meq \ 100 g fat) | Peroxide value PV(meq\ 1 kg) |
|---|---|---|---|
| control C | 1 | 0.42 | 0.33 |
| | 3 | 0.55 | 0.39 |
| | 7 | 0.68 | 0.48 |
| | 14 | 0.72 | 0.63 |
| | 21 | 0.85 | 0.73 |
| T1 | 1 | 0.43 | 0.33 |
| | 3 | 0.56 | 0.39 |
| | 7 | 0.79 | 0.83 |
| | 14 | 1.10 | 1.12 |
| | 21 | 1.20 | 1.45 |
| | 1 | 0.41 | 0.33 |
| T2 | 3 | 0.54 | 0.37 |
| | 7 | 0.65 | 0.46 |
| | 14 | 0.73 | 0.59 |
| | 21 | 0.86 | 0.76 |
| T3 | 1 | 0.40 | 0.33 |
| | 3 | 0.53 | 0.35 |
| | 7 | 0.66 | 0.47 |
| | 14 | 0.74 | 0.62 |
| | 21 | 0.87 | 0.75 |
| | 1 | 0.42 | 0.33 |
| T4 | 3 | 0.51 | 0.33 |
| | 7 | 0.67 | 0.46 |
| | 14 | 0.71 | 0.61 |
| | 21 | 0.84 | 0.74 |
| LSD value | -- | 0.429* | 0.377* |

***(p<0.05)**

**Viscosity**

Viscosity is an important indicator in determining the quality of the yoghurt which was closely related to the stability of the product , the stability of the viscosity of the product is very important for quality characteristics (30). *Streptococcus Salivarius* Subsp *Thermophilus* plays a significant role in the production of some culture agents exopolysaccharides which interact with the protein content of milk and increases in viscosity and improve the quality. The viscosity value for C treatment immediately after manufacturing was 1650 P, while the viscosity for treatment T1 increased to 1760 P and in T2,T3 and T4 were 1600, 1640 and 1620 P respectively. The viscosity values for all treatments after 21 days was 2400 P. This results was agreed with that reported by (33) who found an increase in the viscosity of yoghurt from 2123 P after manufacturing directly to 2307 P on day 21 of storage, this due to the drop in pH value of the yoghurt samples which enhanced the hardness and increased the viscosity .The results also indicated a high viscosity for T1 after 21 days it became 2990 P and for T2, T3 and T4 treatments were 2510, 2480 and 2580 P respectively. This result is in line with result found by (36) who reported a significant increase in (P <0.05) iron fortified yoghurt viscosity as compared to control due to the fact that the iron form bridges or bonds between

casine micelles, which lead to increased cohesion of the protein connection and thus increased viscosity, as well as the presence of polysaccharides which interacted with the protein content of the yogurt and increase Viscosity (2). The results of the statistical analysis, showed a significant difference (P <0.05) in viscosity values during the storage period between treatment C and T1.

**Spontaneous whey Separation**

The Spontaneous Whey Separation usually occurs due to lack of solids or insufficient heating or pH below of 4.4 (20). The results in Table 3 reveals the amount (ml) of the spontaneous whey separated in yoghurt treatments. It has been noticed that the amount of spontaneous whey separated directly after manufacturing for all treatments was 1.00 ml / 50 g. This result is corresponded with (14) which indicated, there was no spontaneous whey in control yoghurt upon storage at (5 ± 1) C°. The volume of spontaneous whey for C treatment was 5.16 ml / 50 g and for T1,T2,T3 and T4 were 4.60, 5.17, 5.11 and 5.12 ml / 50 g respectively. The results showed a decrease in amount of spontaneous whey during storage, the values became after 21 days for C treatment 4.60 ml / 50 g. and For T1,T2,T3 and T4 4.31, 4.57, 4.55 and 4.67 ml / 50 g respectively. The reason of this decrease especially in T1 treatment was due to iron which causes increased rigidity and increased cross-linkages with the protein and the protein aggregation power to hold water. This result agreed with (8) who noticed a decrease in the percentage of the spontaneous whey separation from 55.8% on the first day to 51.3% after 21 of storage due to metabolic activity of culture bacteria and to reducing the net pressure inside of the protein template which reduces the whey separation .The results of the statistical analysis showed that no significant difference (P <0.05) between the treatment C and T1,T2,T3 and T4 during storage period at (5 ± 1) C° of 21days.

**Water holding capacity**

The water holding capacity as shows in Table 3 represents the values of water holding capacity for experimental yogurt samples, for treatment C immediately after manufacturing was 27.24%. This result was consistent with (15), who found 31.1%, while the water holding capacity for T1,T2,T3 and T4 were 28.66, 27.52, 27.99 and 27.95%, respectively. The results showed, there was no significant difference in water holding capacity between treatment C and T1,T2,T3 and T4. The results also showed that water holding capacity was affected by the duration of storage. These results were corresponded with (15) that indicated the water holding capacity for yoghurt samples increased from 31.1% immediately after manufacturing to 31.5% after 14 days of storage due to the reduction in moisture content of yoghurt during storage. While the values after 21 days for treatment C was 36.29% and for T1,T2,T3 and T4 were 38.82, 36.60, 37.01 and 36.97%, respectively. This result is agreed with (1) Who studied the physiological composition of the yoghurt fortified by different mineral elements and was observed a significant increasing in water holding capacity in iron-fortified yoghurt as compared to control treatment. The statistical analysis indicated that no significant difference (P <0.05) between control and all other yoghurt treatments.

**Table 3. Physical properties for yoghurt Control treatment and the non-encapsulated and iron-encapsulated treatments during storage period at (1 ± 5) ° C for 21 day**

| Treatment | Storage period (day) | pH | Acidity % TA | Viscosity (Centipoise) | Spontaneous Whey separation | Water holding capacity |
|---|---|---|---|---|---|---|
| control C | 1 | 4.68 | 0.85 | 1650 | 1.00 | 27.24 |
| | 3 | 4.62 | 0.90 | 1902 | 1.00 | 29.23 |
| | 7 | 4.57 | 0.94 | 2130 | 5.16 | 32.26 |
| | 14 | 4.53 | 0.97 | 2240 | 4.75 | 35.83 |
| | 21 | 4.48 | 0.99 | 2400 | 4.60 | 36.29 |
| T1 | 1 | 4.67 | 0.85 | 1760 | 1.00 | 28.66 |
| | 3 | 4.63 | 0.92 | 2480 | 1.00 | 29.72 |
| | 7 | 4.55 | 0.95 | 2750 | 4.60 | 43.9 |
| | 14 | 4.50 | 0.97 | 2880 | 4.47 | 38.15 |
| | 21 | 4.45 | 0.99 | 2990 | 4.31 | 38.82 |
| | 1 | 4.65 | 0.84 | 1600 | 1.00 | 27.52 |
| T2 | 3 | 4.63 | 0.92 | 2200 | 1.00 | 29.54 |
| | 7 | 4.57 | 0.93 | 2300 | 5.17 | 33.47 |
| | 14 | 4.52 | 0.96 | 2360 | 4.77 | 36.19 |
| | 21 | 4.46 | 0.99 | 2510 | 4.57 | 36.60 |
| | 1 | 4.65 | 0.84 | 1640 | 1.00 | 27.99 |
| T3 | 3 | 4.63 | 0.91 | 2000 | 1.00 | 29.55 |
| | 7 | 4.57 | 0.95 | 2240 | 5.11 | 33.65 |
| | 14 | 4.53 | 0.96 | 2370 | 4.72 | 36.55 |
| | 21 | 4.48 | 0.98 | 2480 | 4.55 | 37.01 |
| | 1 | 4.66 | 0.85 | 1620 | 1.00 | 27.95 |
| T4 | 3 | 4.62 | 0.91 | 3180 | 1.00 | 29.53 |
| | 7 | 4.57 | 0.93 | 2340 | 5.12 | 33.81 |
| | 14 | 4.53 | 0.96 | 2400 | 4.75 | 36.51 |
| | 21 | 4.46 | 0.98 | 2580 | 4.76 | 36.97 |
| LSD value | -- | 0.537 NS | 0.216N S | 326.61* | 1.044* | 4.36* |

**p<0.05) NS (non-significant)**

**Sensory evaluation**

Table 4 represents the results of sensory evaluation (flavor, texture, color, the spontaneous whey and appearance) of the experimental yoghurt samples. It is obvious that T4 (fortified with 15 mg of encapsulated iron) gained the highest total score (98.2) on the day one of manufacturing. The qualities of dairy products fortified by iron was affected by the type of iron salt used. After 21 day of storage at (5 ± 1) C° treatment T1, which was fortified with non-encapsulated iron obtained the lowest scores of sensory evaluation (55.7%) whereas T2, T3, and T4 recorded 67.8, 73.7 and 78.0%, respectively.So, T4 treatment is appeared to be superior to all treatments during 21day as compared to T1 which gained 69.5 during storage period, and as compared to C treatments. The results of the statistical analysis indicated that there was a significant difference (P <0.05) between control and all other yoghurt treatments immediately after manufacture and during storage period (21 days).

**Table 4. Results of the sensory evaluation of the yoghurt treatments control and the iron-encapsulated and non-encapsulated during storage at (1 ± 5) C° for 21 days**

| Treatment | Storage period (day) | Flavor 45° | Textures 25° | Color 10° | Spontaneous Whey 10° | Appearance 10° | Total 100° |
|---|---|---|---|---|---|---|---|
| control C | 1 | 40.5 | 23.0 | 9.2 | 9.6 | 10 | 92.3 |
| | 3 | 36.5 | 20.0 | 7.6 | 9.7 | 8.8 | 82.6 |
| | 7 | 35.5 | 17.0 | 7.3 | 7.3 | 8.2 | 75.3 |
| | 14 | 34.4 | 16.5 | 7.1 | 7.2 | 7.9 | 73.1 |
| | 21 | 32.6 | 15.9 | 6.9 | 6.8 | 7.3 | 69.5 |
| T1 | 1 | 39.3 | 23.5 | 8.6 | 9.8 | 10 | 91.2 |
| | 3 | 31.5 | 20.8 | 8.3 | 9.2 | 7.6 | 77.9 |
| | 7 | 27.0 | 19.1 | 6.3 | 8.3 | 6.4 | 67.1 |
| | 14 | 22.3 | 18.7 | 5.1 | 8.0 | 6.2 | 60.3 |
| | 21 | 20.1 | 17.8 | 4.9 | 7.1 | 5.8 | 55.7 |
| T2 | 1 | 39.6 | 22.0 | 9.0 | 9.4 | 9.7 | 89.7 |
| | 3 | 39.0 | 19.1 | 8.6 | 9.2 | 8.0 | 83.9 |
| | 7 | 33.0 | 17.5 | 8.0 | 7.1 | 8.6 | 74.2 |
| | 14 | 31.8 | 17.1 | 7.8 | 5.9 | 8.4 | 71.0 |
| | 21 | 30.7 | 16.7 | 7.2 | 5.4 | 7.8 | 76.8 |
| T3 | 1 | 42.3 | 24.5 | 9.6 | 9.8 | 10 | 96.2 |
| | 3 | 39.0 | 20.8 | 8.6 | 9.6 | 9.0 | 87 |
| | 7 | 36.0 | 18.3 | 7.6 | 7.6 | 9.1 | 78.6 |
| | 14 | 35.8 | 17.9 | 7.4 | 7.3 | 8.6 | 77.0 |
| | 21 | 34.9 | 17.1 | 7.1 | 6.8 | 7.8 | 73.7 |
| T4 | 1 | 44.1 | 24.5 | 9.6 | 10 | 10 | 98.2 |
| | 3 | 45.9 | 21.6 | 9.0 | 9.9 | 9.3 | 94.8 |
| | 7 | 40.5 | 19.1 | 8.4 | 7.6 | 9.5 | 85.1 |
| | 14 | 39.3 | 18.5 | 7.9 | 7.5 | 9.0 | 82.2 |
| | 21 | 37.9 | 17.9 | 7.4 | 6.9 | 7.9 | 78.0 |
| LSD value | -- | 5.26* | 3.53* | 2.06* | 2.88* | 2.37* | 7.82* |

***(p<0.05)**

## REFRENCES


1. Achanta, K.; K. J,Aryana. and A.C. Boeneke. 2007. Fat free plain set yogurts fortified with various minerals. LWT-Food Science and Technology, 40 (3): 424-429

2. Al-Mousawi, B.N.E. and , E.K., Apd-Aljabar.2018. Study of the effect of wheat germ extract on the production of exopoiysaccharides from the bioenhancers. The Iraqi Journal of Agricultural Sciences,49(1): 58-63

3. Alrubeii,A.M. and Alalaq, M.M., 2018. The bio-preservation of buffalo meat manufactured (pastrama) by using lactobacillus plantarum bacteria. The Iraqi journal of agricultural sciences, 49(1):152-159

4. Amatayakul, T.; F. Sherkat and , N. P. Shah .2006. Syneresis in set yogurt as affected by EPS starter cultures and levels of solids.Int. J. Dairy Tech. 59. 216–221

5. Association of Official Agricultural Chemists – AOAC. 2005. Official Methods of Analysis of AOAC International, 18th ed. Maryland: AOAC International

6. 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

7. Bahrami,M.;,D.; M ,Ahmadi. Alizadeh and F ,Hosseini,. 2013. Physicochemical and sensorial properties of probiotic yogurt as affected by additions of different types of hydrocolloid. Korean J. Food Sci. 33:363-368

8. Çelik, E.S. 2007. Determination of Aroma Compounds and Exopolysaccharides Formation by Lactic acid Bacteria Isolated from Traditional Yogurts. M.Sc.Thesis in Bio. Izmir University

9. Champagne, C. P., and P. Fustier. 2007. Microencapsulation for the improved delivery of bioactive compounds into foods. Current Opinion in Biotechnology, 18(2), 184-190

10. Chandan, R.C. 2015. Health Benefits of Yogurt. Health Benefits of Fermented Foods and Beverages,pp**12)(**275

11. Chandan, R.C. and, K.R, O'Rell .2006. Principles of yogurt processing. In: Chandan, R .C. and et al , Editors. Manufacturing Yogurt and Fermented Milks. Ames: Blackwell Publishing pp: 209-195

12. Deeth, H.G. and,C.H, Fitz_gerald .2004. Lipolysis in Dairy Products. review. Aust. J.Dairy.Tech.31:53

13. Donkor ,O.N.; S.L., P ,Nilmini.; Stolic.; T ,Vasiljevic. and N.P ,Shah. 2007.Survival and activity of selected probiotic organisms in set-type yoghurt during cold storage. Int. Dairy J. 17, 657-665

14. Gupta, C. 2013. Development and evaluation of microencapsulated iron fortified yoghurt. (Doctoral dissertation, NDRI, Karnal)

15.Ibrahim, K.J. 2015. Purification and Characterization of Karadi Sheep's Milk Protein and its Relationship with Yoghurt Quality.M.S.Thesis. Sulaimani University

16. Ihokoronye , A. 1985. Integrated Food Science and Technology for the Tropics, 26. Mc Millan press Ltd London pp

17. ISO 3976lIDF 74. 2006. Specifies a method for the determination of the peroxide value of anhydrous milk fat

18. Jayalalitha,V.; B ,Balasundaram.; P ,Dorai. and N.P ,Kumar. 2012. Fortification of encapsulated iron in probiotic yoghurt. International Journal of Agriculture: Research and Review, 2 (2): 80-84

19. Khosroyar, S.; A ,Akbarzade.; M ,Arjoman.; A. A ,Safekordi. And S.A, Mortazavi 2012. Ferric – saccharate capsulation with alginate coating using the emulsification method. African Journal of Microbiology Research, 6 (10): 2455-2461

20. Konhorst, A. 2007. The Technology of Dairy Products.Food Science and Technology. U.S.A

21. Ling, E.R. 2008. A Textbook of Dairy Chemistry. Vol. II Practical, Chapman and Hall. LTD, (London)

22. Lobo, V., A, Patil.; A Phatak. and N ,Chandra. 2010. Free radicals, antioxidants and functional foods: Impact on human health. Pharmacognosy Reviews, 4(8).118

23. Martirosyan,D.M. and J ,Singh. 2015. A new definition of functional food by FFC: what makes a new definition unique.J. of Func. Foods in health and disease; 5, 209-223

24. McSweeney, F., and F ,Patrick. 2013. Advanced Dairy Chemistry: Volume 1A: Proteins: Basic Aspects. Springer

25. Nawar, G.A.M.; A.M.H ,Fatma.; K.E ,Ali.; M.K ,Jihan. and H.S.M, Sahar. 2010. Utilization of microcrystalline cellulose prepared from rice straw in manufacture of yoghurt. J. American Sci. 6.226-231

26. Nelson, J.A. and G.M ,Trout. 1964. Judging Dairy Product .the Olsen Publishing Co., Milwaukee, Wis.53212, USA

27. Parnell-Clunies ,E.M.; Y ,Kakuda.; K ,Mullen.; D.R ,Arnot. and J.M ,DeMan,. 1986.Physical properties of yogurt: A comparison of vat versus continuous heating systems of milk. J Dairy. Sci. 69:2593-2603

28. Qureshi, A.M.; Y,Hassan ., M ,Sulariya. and A ,Rashid. 2011. Preparation and nutritional evaluation of garlic Based yogurt. Sci. Int. Lahore 23: 59-62

29. Roberfroid, M.; M ,Champ. and G,Gibson. 2002. Nutritional and health benefits of inulin and oligo fructose. Br. J. Nut. l.2:S139-S311

30. Salih, F.A., R.H ,Oumar. and K.S, Abaas, 2018. Effect of zinc salts fortification on nitrogen materials and rheological characteristic of soft white Iraqi cheese. Iraqi Journal of Agricultural Sciences, 48(6 B).1773-1781

31. SAS. 2012. Statistical Analysis System, User's Guide. Statistical.Version 9.1$^{th}$ ed. SAS .Inst. Inc. Cary. N.C. USA

32. Sengupta, S.; C ,Ankita. and B ,Jayat,. 2014. Production and evaluation of yogurt with watermelon juice. J. Int. Academic Research for Multidisciplinary. 2, (Issue 5)

33. Shaghaghi, M.; R ,Pourahmad. and A.H.R ,Mahdavi. 2013. Synbiotic yogurt production by using prebiotic compounds and probiotic lactobacilli.Int . Res J. of Applied Basic Sci.5(7): 839-846

34. Stijepic. M.; J ,Glušac.; D,Đurdević-Milošević. and D ,Pešić-Mikulec.. 2013. Physicochemical characteristics of soy probiotic yoghurt with inulin addition during the refrigerated storage. Romanian Biotech Letters, 18(1

35. Tandara, L. and I ,Salamunić. 2012. Iron metabolism: current facts and future directions. biochemical medical: Biochemical medical 22(3),.311-328

36. Walstra P.; J.T.M ,Wouters. and T.J, Geurts. 2006. Dairy science and technology, 2$^{nd}$ edn. Boca Raton, FL, USA: CRC Taylor and Francis

37.Yilmaz-Ersan, L. and E, Kurdal.2014.the production of set-Type-bio-yoghurt with commercial Probiotic culture. Int. J.Chem. Eng. and Appl.5:402-408