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Effect Of Sodium Pyrophosphate Addition To The Milk On Yogurt's Rheological Properties

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Abstract

This study was applied and aimed at specifying the effect of adding sodium pyrophosphate (SSP salt) to the milk prepared for yogurt manufacturing on pH and the rheological properties of yogurt. This could be occurred by adding (SPP salt) to the full fat reconstituted dried bovine milk before and after heat treatment at 90 Cº for 10 minutes with rates of 0.05, 0.1, 0.2, 0.3 % respectively. Tests that involved are pH and rheological properties which include viscosity, spontaneous whey separation, percentage of water holding capacity, and hardness directly after manufacturing and during storage at (5± 1) Cº for 14 days. Results have shown that yogurt treatments with the addition of SPP salt before heat-treatment had increased pH value compared to the control and also have an applicable rheological property within extended ratios 0.05, 0.1 and 0.2 % compared with the same properties for addition treatments after the heat treatment.

Keywords: Sodium pyrophosphate, yogurt, rheological properties, viscosity, percentage of water holding capacity, hardness.

Introduction

Yogurt is a popular dairy drink [1]. It has an exact place of origin, and it is thought to be the earliest fermented product known to humans ever. The Middle East is supposed to be its place of origin with a history going back to a thousand years since the domestication of cows, sheep, and goat [2].

FDA (2009) has defined yogurt as the nutritional product produced by lactic acid bacteria and have in its texture one or more of the following dietary compositions (cream, milk, partially or fully skimmed milk)[3], in addition to the lactic acid bacteria *Lactobacillus bulgaricus* and *Streptococcus thermophilus* as culture bacteria [4].

Yogurt is used widely around the world because of its high nutritional value with some therapeutic properties[5]. Biotechnical products, such as yogurt, are considerable nutritional sources with high protein, carbohydrates, fat, vitamins, calcium and phosphor. The distinction of yogurt from other products is due to the type of fermentation (lactose to lactic) during manufacture, making it easily digestible [6], in addition, this procedure increases the calcium bio-availability in the alimentary canal [7]. The healthy benefits of yogurt are attributed to the starter bacteria. Yogurt has many benefits, of these are treating digestive system disturbances [8], reducing cancer risks, reducing cholesterol levels in the blood and improving lactose digestion especially for cancer patients who have lactose intolerance [9].

It is known that emulsifying salts have a vital benefit on manufacturing processed cheese by controlling the pH, matrix and texture required in cheese and controlling cheese spoilage. Also, these salts aid in mixing the protein, fat, and water in one homogeneous soft mass by reducing para-casein molecule volume and producing the wanted short matrix. International companies have developed mixtures of these types of salts for in different purposes according to the type of the initial materialand type of the wanted processed cheese (whether a spreadable cheese or cheese molds) [10].

Effect of adding emulsification salts either separately or like a mixture on the manufacture of different kinds of processed cheese are reported previously and Generally, the effect of adding these salts is restricted on the pH and the physical properties [11,12].

It is also known that these mineral salts play an important role in forming and stabilizing of casein molecules [13]. There is a kinetic equilibrium relationship between the mineral salts and the casein.Any changes in the distribution of calcium phosphate between the two phases - the dissolved and the non-dissolved - can lead to significant effects on casein stability. The state of casein and minerals in

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milk are affected by many factors like pH, temperature, and the addition of calcium chelating agents [14,15].

The current study aims to investigate the effect of adding sodium pyrophosphate salt to the milk prepared for yogurt manufacture, before and after subjecting it to heat treatment, on the pH and rheological properties of yogurt.

Materials and Methods

Materials:

Full fat powdered milk (Al-Mudhish- Oman State) from Hilla city local markets, SPP salt from (Alwernia company – Holland).

Methods:

Yogurt Manufacturing: the yogurt was made according to Tammime and Robinson(1999) [16]method as follows: skim milk was reconstituted as 1:9 ratio (powdered milk : water) using distilled water then divided into three groups. The first group left without any SPP salt addition and used as control treatment D, while the second group was divided into four treatments with the addition of SPP salt as D1a, D2a , D3a and D4a treatments at ratios of 0.05 ,0.1 ,0.2, 0.3% respectively before the heat treatment. The same ratios of SPP salt were added to make the third group which is represented by D1b, D2b, D3b and D4b treatments after the heat treatment. All milk groups were heated at 90 Cº for 10 min., then cooled down to 42 Cº and inoculated by direct addition of the starter culture that contains Streptococcus Salivarius subsp thermophiles and Lactobacillus delbrueckii subsp bulgaricus, followimg the instructions provided by the producing company (Danisco – France). After that, it was packaged in plastic containers and incubated at 42 ± 2 Cº till fermentation and stored in the refrigerator till performing the required tests, directly after manufacturing and during the storage for 14 days.

Physical tests:

pH of the yogurt treatments was evaluated using a pH meter (Model 211 type (HANNA Instruments Microprocessor, Romania). Viscosity was determined according to Donkor et al (2007) [17] method by using Brookfield DVII + Viscometer (Brookfield Engineering Lab Inc., Stoughton, Mass), at 10 C° after the 1st and the 14th days of refrigerated storage. Water holding capacity was determined according Shori et al (2013) [18] method by exposing 10 g of the yogurt sample to a centrifugal force at a speed of 9,800 xg for 20 min at 4 Cº, Then, the permeate was collected and weighed. Water retention was calculated using the following equation:

$$WHC\ (\%)=(1-W1W2)\times 100$$

W1: Weight of the pellet after centrifugation, W2: Initial weight of the sample.

Whey exudation was determined according to Amatayakul (2006)[19] method by placing the yogurt bowl at an angle of 45 o for 2 hours at 5 C○ and draining the whey exudate at the surface using a syringe then the volume was determined. The firmness analysis was carried out according to the method mentioned by Bonczar et al (2002)[20] using the Brookfield CT3 texture analyzer with a 2 cm diameter plastic cylinder that was projected at a strength of 5 g on the product to penetrate a 2 cm depth at a speed of 1 mm / sec.

Results and discussion:

pH: The results in figure 1 shows that the pH of the control treatment was 4.64, while those of the yogurt treatments with different ratios of SPP salt before the heat treatment were 4.73 , 4.74 , 4.80 , 4.79 for D1a, D2a, D3a, and D4a respectively, and those of the treatments with SPP salt addition after the heat treatment D1b, D2b, D3b, and D4b were 4.77 ,4.64 ,4.70 ,4.72 respectively, immediately after manufacturing.

The difference in yogurt pH values may be due to the role of the added phosphates in influencing the pH by acting as a buffering agent [21].

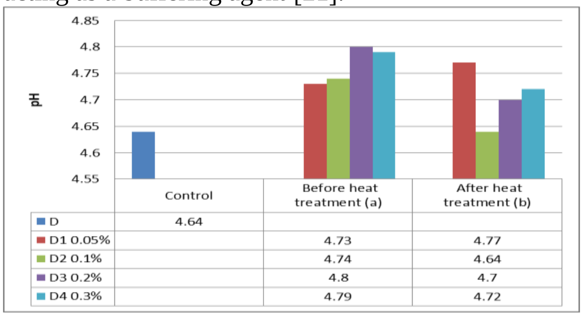

Fig.1. The effect of adding SPP salt on the pH of different yogurt treatments immediately after manufacturing.

The results in figure 2 shows a decrease in pH values for all treatments with storage. After 14 days at 5C°, The control treatment reached 4.5, while the pH values for treatments before the heat treatment reached 4.57 , 4.59 , 4.64 , 4.68 for D1a, D2a, D3a, and D4a respectively. On the other hand, pH values for treatments after the therminsation reached 4.6 , 4.55 , 4.49 , 4.88 for D1b, D2b, D3b, and D4b respectively. These results are in consistent with Maragkoudakis *et al* (2006)[22] who mentioned that the pH of the Greek yogurt decreased from 84.6 immediately after manufacturing to 4.24 after 14 days of storage and this was agreed with what Marafon *et al* (2011) found [23].

The decrease in pH values with storage is due to the continued activity of starter bacteria, which convert lactose into lactic acid during storage, yet it is a slow process[24].

It is noted that pH value of the yogurt treatment with the 0.3% of SPP salt addition ratio after the heat treatment was increased and the reason for that may be attributed to the high concentration of phosphate salts that act as a buffer to neutralize the acidity and to prevent pH decline [25]. What supports this claim is the loose texture of this treatment, whichis semi-liquid. This indicates that the increase in the concentration of SPP salt would lead to raise the pH and prevent the achievement of the electrical neutralization point of casein PI (4.6) and thus weakening the formed yogurt gel.

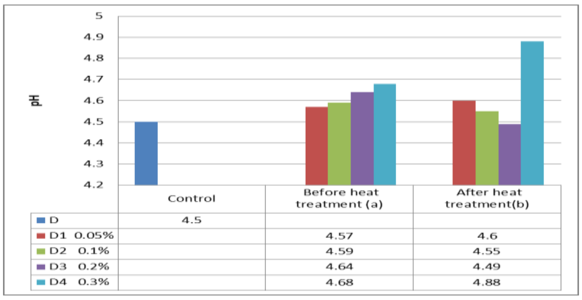

Fig.2. The effect of adding SPP salt on the pH of different yogurt treatments after 14 days of storage at (5 ± 1) C°.

Viscosity: Figure 3 shows the viscosity values for the different yogurt treatments, that of the control treatment was 5060 centipoise immediately after manufacturing, while those of the SPP salt added treatments before the heat treatment were 6500,6820,7010,8010 centipoise for D1a, D2a, D3a, and D4a respectively and those of the SPP salt added treatments after the heat treatment were 3310 , 5050 , 5340 , 250 centipoise for D1b, D2b, D3b, and D4b respectively. The increased viscosity values for all SPP salt added treatments before the heat treatment and the decreased viscosity values for the treatments after the heat treatment are recorded in comparison with the control treatment. This may be because of SPP salt ability to transform into colloidal state and binds within the casein particles due to the effect of heat treatment, leading to the formation of complexes of high molecular weights with milk proteins that increases the viscosity [25].

It is also noted from the results that the viscosity values for all treatments are affected by storage, as it reached to 4950 centipoise for the control treatment after 14 days of storage in comparison to the viscosity of the SPP salt added treatments before the heat treatment that reached to 5830 , 7310 , 4390 , 5590 centipoise for D1a, D2a, D3a, and D4a respectively, while the viscosity values of the SPP salt added after the heat treatment were 5630 , 5300 , 5290 , 580 centipoise for D1b, D2b, D3b, and D4b respectively.

It is also observed that the viscosity values tend to increase for all the yogurt treatments with storage, this is consistent with Maragkoudakis *et al* (2006) [26] who found a rise in the viscosity of yogurt from 20,000 Centipoise, immediately after manufacturing, to 26,000 Centipoise after 14 days of storage.

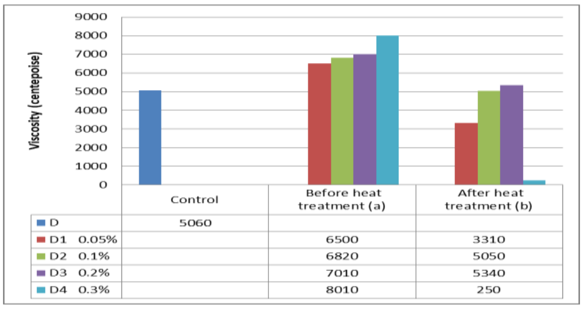

Fig.3. The effect of adding SPP salt on the viscosity of different yogurt treatments immediately after manufacturing.

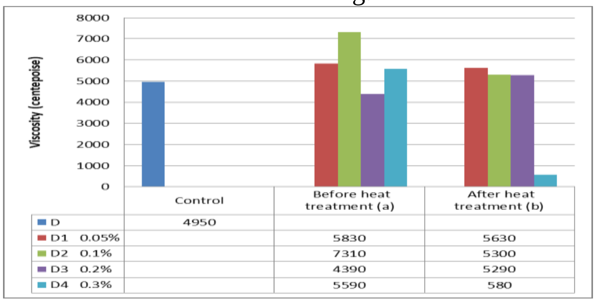

Fig.4. The effect of adding on the viscosity values of different yogurt treatments after 14 days of storage at (5 ± 1) C °.

Water holding capacity: this parameter illustrated in figure 5 has reached to 66.6 , 69.3 , 73.0 , 85.8% for D1a, D2a, D3a, and D4a respectively for the SPP salt added treatments before heat treatment and for the SPP salt added treatments after heat treatment were 52.5 , 62.5 , 76.0 , 10.0% for D1b, D2b, D3b, and D4b respectively and 65.0% for the control group.

The increased water holding capacity of the SPP salt added treatments before the heat treatment was obviously noted in comparison to the lower values for the SPP salt added treatments after the heat treatment, and this may be due to interaction between the milk proteins and calcium with helping of SPP salt, leading to form a stronger protein network with higher interactions that contributed in increasing the water retention **[**28**]**. The high buffering capacity provided by the phosphate salts would delay the yogurt acidification, leading to improved susceptibility to water retention, therefore the yogurt develops a uniform composition, more connected, with smaller pores that hinder the whey extrusion. Lee and Lucey (2004) found that rapid acidification leads to increasing the separation of the whey due to the rapid restructuring of the casein network**[**29**]**.

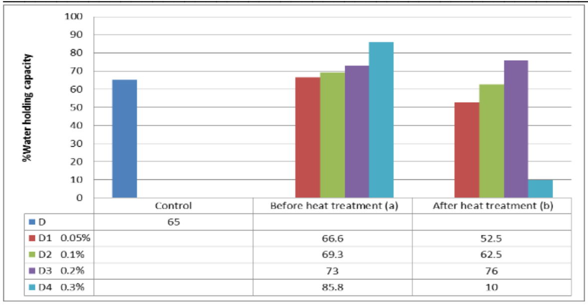

Fig.5. effect of the SPP salt addition on water holding capacity of different yogurt treatments immediately after manufacturing.

Yet with storage, it is noticed that the water holding capacity was increased for all treatments, this is consistent with what Narayana and Gupta (2018)**[** 30-31**]** found, that the water holding capacity of the raspberry-enriched yogurt raised from 70.57% to 72.94% after 16 days of refrigerated storage. Similar results obtained by Sichani *et al* (2014) **[**32-33**]** in a low-fat yogurt with seed gum and locust bean gum. Singh and Muthukumarappan (2008)**[**34**]** reported that when studying the ability to retained water in the control treatment and other yogurt treatments supported by calcium and fruit, this ability have been increased significantly throughout the first 7 days of storage, then it remained constant till the 14th day. This may be due to the evolution of the protein network with the advance of storage**[**35-36**]**. Yet, these results do not agree with Kücükcetin *et al* (2011) [37**]** findings on yogurt made from cow's milk, in which it was found a decrease in water retention capacity with storage.

From the foregoing, it can be said that changes in the ability to retain water during storage are not a condition that is directly related to whey separation but insteadthe increase in the size of the particle and the increase in the interaction of whey - casein and casein - casein would lead to form a gel-like structure with larger pores that retain more water **[**38-39**]**.

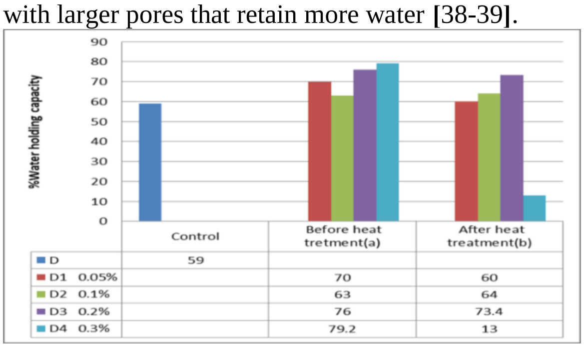

Fig.6. The effect of the SPP salt addition on the water holding capacity of different yogurt treatments after 14 days of storage at (5 ± 1) C°.

Spontaneous whey separation: It means that the fluid is exiting in the yogurt gel and accumulates on the surface which occurs when the amount of whey in the inside of the yogurt gel exceeds the melting point with the temperature change. Whey separation is an undesirable change in which liquid phase separation occurs in products of a gelatinous nature**[**40**]**. The results in figure 7 show the whey separation values, being 6.0 ml / 100 gm for the control treatment, while those of the SPP salt added treatments before the heat treatment were 3.0 , 4.0 , 6.2 , 7.1 ml / 100 g, for D1a, D2a, D3a, and D4a respectively, and those of the SPP salt added treatments after the heat treatment were 3.2 , 5.7 , 6.8 , 12 mL / 100 g, for D1b, D2b, D3b, and D4b respectively. From the results, it is clear that the syneresis values of the SPP salt addition treatments before the heat treatment were decreased in comparison to those treatments after the heat treatment, and this may be because of the SPP salt added to the milk before the heat treatment had interacted with the milk proteins and calcium, thus it may have contributed in reducing the whey separation**[**36**]**. Harwalkar and Kalab (1986)**[** 41-42**]** also pointed out that a high-buffering yogurt has a reinforced protein network that reduces whey separation for that whey ejection is affected by the rigidity of the protein matrix. It is also noted from the results that the whey separation increased with the raise in the percentage of salt addition for all the addition treatments, and this is consistent with the findings of Ozcan *et al* (2008) **[**43**]**, who indicated that the addition of sodium triphosphate at levels higher than 0.1% increases the whey separation.

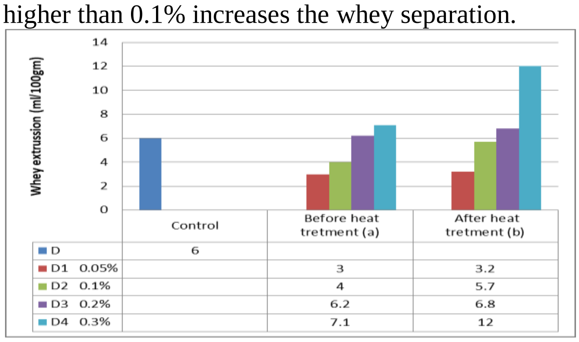

Fig.7. effect of the SPP salt addition on spontaneous whey separation values of different yogurt treatments immediately after manufacturing.

It is also noted that the whey separation values (figure 8) decreased for all the treatments with storage, as after 14 days it reached 0.7 , 1.2 , 2.0 , 4.0 ml / 100 g for D1a, D2a, D3a, and D4a respectively for the SPP salt addition treatments before heat treatment, and for the SPP salt addition treatments after heat treatment it reached 4.2 , 3.1 , 4.2 , 8.6 ml / 100 g, for D1b, D2b, D3b, and D4b respectively, while for the control treatment it reached 2.6 ml / 100 gm. Güler-Akın and Akın(2007) **[**44-45**]**, attributed this behaviour to the metabolic activity of the starter's bacteria and to the decrease in the net pressure within the protein matrix, which reduces syneresis.

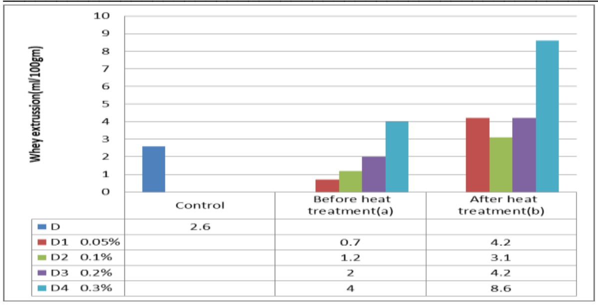

Fig.8. The effect of the SPP salt addition on spontaneous whey separation values of different yogurt treatments after 14 days of storage at (5 ± 1) C °.

Firmness: Firmness is a measure of the structural network strength of the yogurt protein component. It is noted from Figure 9 that the firmness of the addition treatments before heat treatment had increased with increasing the concentration of the SPP salt added in all addition ratios except in 0.3% as it reached 66.0 ,60.0 ,76.0 g for the addition ratios of 0.05 , 0.1 and 0.2%, for for D1a, D2a and D3a respectively, and no firmness for the D4a treatment, this is consistent with what Ozcan *et al* (2008) found **[**41**]**, that is adding sodium tri-citrate at levels higher than 0.1%, led to the production of very weak yogurt gel. Lee and Lucey (2004a,b) and Ozcan Yilsay *et al* (2007) **[**29,30,46**]**indicated that this weak yogurt gel results in a high whey exudation. This increment also applies on the firmness of the yogurt treatments after the heat treatment at the same addition ratios, as it reached 53.5 , 53.0 , 57.0 g for D1b, D2b and D3b respectively, while there was no firmness for the D4b treatment of the addition ratio 0.3 %. The control treatment firmness was 68.5 g. It is also observed that the firmness of the SPP salt addition treatments before the heat treatment was increased in comparison to the firmness of the SPP salt addition treatments after the heat treatment at addition ratios of 0.05 , 0.1 , 0.2%.

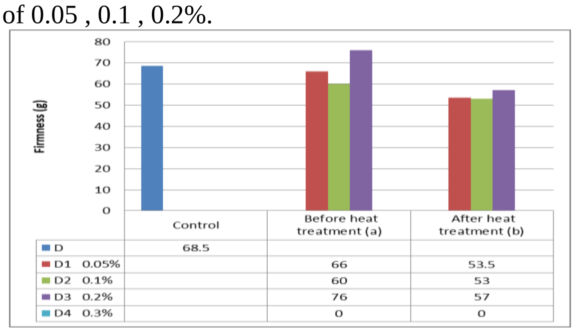

Fig.9. effect of the SPP salt addition on firmness values of different yogurt treatments immediately after manufacturing.

Furthermore, an increment in firmness with storage for all the treatments (figure 10) that it reached to 93.0 , 71.0 , 103.5 g for the SPP salt addition treatments before the heat treatment for D1a, D2a, D3a, and D4a respectively, and 71.0 , 66.5 , 60.5 g for D1b, D2b, D3b, and D4b respectively for the SPP salt addition treatments after the heat treatment, while for the control treatment reached to 70 g. This is consistent with what Maragkoudakis *et al* (2006) **[**26**]**found, who pointed the rise in the firmness of the Greek yogurt from 94 g to 112 g after 14 days of storage.

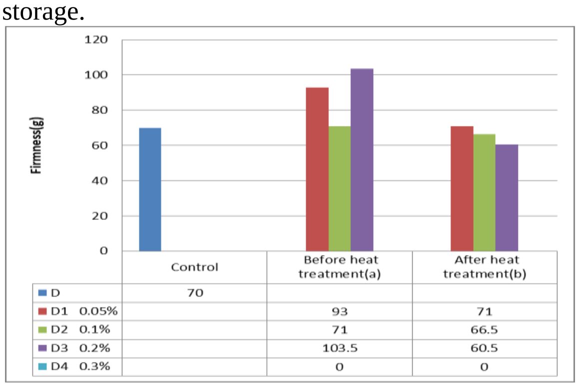

Fig.10. The effect of the SPP salt addition on firmness values of different yogurt treatments after 14 days of storage at (5 ± 1) C °.

Conclusions:

To improve the properties of the yogurt, sodium pyrophosphate(SSP salt) was added to the milk prepared for yogurt manufacturing and the effects on pH and the rheological properties of yogurt were investigated. Four concentrations of SSP salt were added to the full fat reconstituted dried bovine milk before and after heat treatment at 90 C° for 10 minutes and its properties were studied such as pH and rheological properties which include viscosity, spontaneous whey separation, percentage of water holding capacity, and hardness directly after manufacturing and during storage at (5± 1) C ° for 14 days. Results have highlighted that yogurt treatments with the addition of SPP salt before heat-treatment had increased pH value in comparison to the control and also have an improved rheological property within extended ratios(0.05 , 0.1 and 0.2 %) in compared with the same properties for addition treatments after the heat treatment. These results are important for finding new approaches to improve the yogurt properties and better customer's experience.

Conflicts of interest:

There are no conflicts to declare.

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