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STUDY OF THE EFFECT OF FORTIFIED MILK BY ZINC SALTS IN DIFFERENT CONCENTRATIONS ON THE SENSORY AND PHYSIOCHEMICAL PROPERTIES OF THE PROCESSED YOGURT

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Abstract

The present study was conducted with the aim of fortifying the milk prepared for the manufacture of yoghurt with different concentrations of zinc salts in order to raise its level in the manufactured product, and the development of non-traditional therapeutic dairy products with health benefites. Yogurt was produced from whole milk fortified with two concentrations of zinc salts of 100 and 200 mg / 1 liter milk, as well as the control experiment in which the yogurt was made from whole milk without the addition of zinc. One of our most important results is that the zinc-fortified yogurt coefficients maintained a moisture content comparable to the moisture content of the control treatment and when tracking moisture values at storage at (5 ± 1) °C for 14 days it was observed that there was a slight decreased in their values for all treatments. While for the percentage of protein and fat were similar in their proportions in all treatments and a slight and insignificant increase in their percentage at storage. As for carbohydrates and ash, there was no significant differences ($P < 0.05$) in their percentage immediately after manufacturing with a slight decrease in carbohydrates and an increase in ash values with storage and it was not significant, and for total acidity and pH values were also comparable for all yoghurt treatments immediately after manufacturing. At storage, a significant increase in total acidity values was observed for all treatments and a significant decrease in pH values. The zinc-fortified yogurt, especially T2 treatment, were characterized by a decrease in acid degree value, pH and peroxide value immediately after manufacturing as well as in all subsequent storage periods compared with the control treatment which has a high values and improved zinc added to the yogurt from the values of rheological properties, which included viscosity and whey drainage. The results of the sensory evaluation indicated the superiority of zinc-fortified yogurt treatments, in particular the treatment of T2 with a concentration of 100 milligrams, which obtained the highest scores and excelled in all sensory characteristics compared with control treatment C.
Keywords : Fortified, zinc salts, yogurt

Introduction

Zinc is an important component of human health and is a micronutrient nutrient that a person needs to grow and prevent a number of diseases (Bhowmik *et al.*, 2010). Zinc functions in the body can be divided into three categories: catalytic, structural and organizational, catalytic as nearly 100 different enzymes depend on zinc for its ability to stimulate biochemical reactions, while the structural function of zinc plays an important role in the synthesis of proteins and cell membranes, as cell membranes are affected by the availability of zinc in them, however, the regulation function found that zinc plays an important role in regulating gene expression by acting as a catalyst. Zinc also plays an important role in nerve and cell signaling as it affects hormone release and nerve impulse transmission (Bhowmik *et al.*, 2010). International organizations concerned with human health and food FAO/WHO, (2004) pointed out that zinc is the basis and aco-enzymatic of more than 300 enzymes that contribute to the construction and destruction of carbohydrates, proteins, peptides and nucleic acids such as carbonic anhydrase found in red blood cells important in the precipitation of calcium salts in Bones and teeth as well as alcohol dehydrogenase and laticdehydrogenase are important in the process of glycolysis and other enzymes (Bhowmik *et al.*, 2010), As well as metabolic processes for the remaining trace elements, it also plays a major role in the immune system, Numerous studies and research have indicated the presence of zinc in more than 300 enzymes covering all six enzyme varieties, as well as many physiological activities that need zinc presence, Zinc also maintains the form or structure of a number of non-enzymatic proteins. Walingo, 2009; Soetan *et al.*, 2010; Aquilanti, 2012). The low intake or absorption of essential minerals such as zinc leads to some defects and disorders which in turn are associated with many human health problems such as stopping growth in children and immune system disorders (Santillan-Urquiza *et al.*, 2017). Numerous studies have shown that zinc deficiency is associated with a decrease in the body's ability to burn energy and metabolism and is also associated with low thyroid levels, as well as the impact of zinc deficiency on the high level of triglycerides and increase the body's ability to accumulate fat in cells, zinc also plays a key role in a number of vital processes, it is essential for cell growth and development for example produce and grow new skin cells, protect against certain heart disease and reduce signs of premature aging, promote healthy hair, balance hormones and strengthen the immune system and memory and strengthen the functions of the nervous system and the health of the reproductive system, especially in men as zinc affects prostate function and hormonal activity for men and their ability to produce sperm. Zinc is also a powerful antioxidant and anti-inflammatory (Chowanadisai *et al.*, 2004; Maret and Sandstead, 2006; Ocak and Kose, 2010; Lee, 2018). Hess and Brown, (2009) proved that fortifying food with absorbable zinc salts increases the supply of the required amounts to the body and enhances the total amounts of zinc. Therefore, food fortification is the best option and a successful strategy to control the shortage of mineral elements, in particular zinc deficiency (Clementi *et al.*, 2012). Milk and dairy products are an ideal source of nutrients important for human health such as calcium, magnesium and phosphorus, as well as large nutrients such as proteins, fats, carbohydrates and some vitamins, but they are poor in some rare elements and important for the vital activities of the body such as iron and zinc (Ocak and Kose, 2010). The US Food and Drug Administration (FDA, 2011) has identified yogurt as a food product produced by a bacteria startars that consists of a mixture of bacterial farms that contain a microorganisms produced lactic acid such as *lactobacillus bulgaricus* and *Streptococcus thermophiles*, It provides the body with many benefits of being rich in nutrients such as protein, calcium, fat and vitamins such as vitamin D, riboflavin, vitamin B6 and vitamin B12. In addition, yogurt is more beneficial than milk due to the presence of live therapeutic bacteria important to the digestive system, which can lead to health benefits when consumed in sufficient quantities (Cheng, 2010). Since yogurt is one of the most consumed foods in the world, it provides the consumer with a number of micronutrients, as well as macronutrients in the diet. It is also a low-cost means as well as a basic or semi-daily food for many people. Therefore, this study aimed to fortified yogurt, which is one of the best ways to compensate for the lack of zinc in food in food and to meet the daily need of it. In addition, the aim of the study was to manufacture yogurt, which is fortified with zinc salts in more than one concentration and study the sensory, physiochemical and rheological properties of yogurt immediately after manufacturing and during storage at (5 ± 1) °C for 14 days.

Materials and Methods

Milk Source

The raw cow's milk was purchased from farms in the holy city of Najaf.

Zinc Source

Zinc as sulphate zinc was used in this study. Zinc was added after pasteurization and before rennet at 40 °C and then filled and incubated in the incubator.

The starter used in the manufacture of yogurt

Strains of Streptococcus Salivarius Subsp thermophilus and Lactobacillus delbrueckii Subsp bulgaricus produced by the French company Danisco were used by adding them directly in the mixtures of yogurt.

Testing of Milk

Milk samples were taken and the whole fat milk ingredients used in the manufacture of yogurt were tested using the lactoflash dairy instrument. The percentage of fat, protein, total solids and non-fat solids were estimated.

Manufacture of yogurt

The yogurt was made according to the method adopted by Tamime and Robinson. (1999) As follows: A quantity of raw cow's milk was received from the farm and heated to 90 °C for 10 minutes and then cooled to 42 °C and then divided into two halves, the first half was left untreated and used in the manufacture of yogurt treatment control C, the second half was divided into two parts added zinc salts in concentrations of 100, 200 mg/L represented by the treatments T1 and T2, The samples were mixed with an electric mixer to ensure good mixing, and were inoculated with Streptococcus Salivarius Subsp thermophilus and Lactobacillus delbrueckii Subsp bulgaricus indicated by the French manufacturer Danisco (3%) and packed in 150 mL plastic containers and incubated at a temperature of 42 ± 2 °C until the coagulation was about 3.5 hours until pH was reduced to 4.6, it was removed from the incubator and transferred to the refrigerator for cooling and storage at a temperature (5 ± 1) °C until the necessary tests after 1, 3, 7, 14 days after manufacturing.

Estimate the amount of zinc in milk and yogurt

The amount of zinc in milk and yogurt was estimated using the Atomic Absorption Spectrophotometer at a wavelength of 213.9 nm (Horwitz, and Catimer, 2005).

Physicochemical analysis of the yoghurt

The percentage of moisture, total acidity, fat and ash was estimated according to A.O.A.C, (2008), while protein and fat were estimated according to Ling, (2008).

Determination of carbohydrates in yogurt

Carbohydrates were calculated in a computational way, according to Ihekoronye and Ngoddy (1985). % Carbohydrates = 100 -% (ash + protein + fat + moisture).

Determination of pH

Determine the pH of the yogurt models by placing a pH meter sensor (Model 211 type HANNA (Instruments Microprocessor)) of Roman origin, directly in the sample of the yogurt.

Determination of viscosity

The apparent viscosity of the yogurt samples was estimated at 10 °C after 1, 3, 7 and 14 days of refrigerated storage using Brookfield DVII Viscometer equipped by Brookfield Engineering Lab Inc., Stoughton, Mass. The axial spindle number 4 was used and the number of cycles 10 r/min and the volume of 150 ml of the sample left the spindle to rotate inside the sample for 60 seconds after the gel was broken by moving it 10 times clockwise and 10 times counterclockwise, and the reading was taken three times and the rate in centipoise units was recorded (Donkor *et al.*, 2007).

Estimation of whey drainage

The whey was drained by placing 50 ml of yogurt in a 45 °C inclined cup for 2 hours at 5 °C, withdrawing the aspirated whey from the surface using the syringe and then re-weighing the cup. The procedure was performed within 10 seconds to avoid excessive perfusion.

Determination of Acid degree value and peroxide number

The acid degree value was determined according to Deeth and Fitz-Geraid (2004) and the peroxide number of yogurt according to the A.O.A.C. (2008).

Sensory Evaluation of Yougurt

The sensory tests of yogurt were conducted in the Department of Food Science, Faculty of Agriculture, University of Kufa by ten professors and 10 students, according to the sensory evaluation form, which included the characteristics of flavor, texture, color, appearance and acidity, developed (Nelson and Trout, 1964).

Statistical analysis

Complete Random Design (CRD) and factorial experiments were used to study the interaction between the different coefficients in some of the characteristics of the yogurt. Significant differences between the averages were compared with the least significant difference (LSD) test and the use of Gen stat (2012) in the statistical analysis of the studied data.

Results and Discussion

Chemical composition of milk used in the manufacture of yogurt Table (1) shows the percentages of moisture, fat, protein, total solids and non-fat solids of raw whole fat cow milk, which is 86.16, 3.55, 3.7, 13.84 and 10.29%, respectively, while the pH and titration acidity (calculated on the basis of lactic acid) and specific gravity are 6.64, 0.16 and 1.023, respectively, and these ratios are within the natural limits of milk and close to what he found by (Yilmaz-Ersan and Kurdal, 2014; Al-Shaikh, 2018).

Table 1 : Chemical Composition of Full Fat Raw Cow Milk Used in the Manufacture of Yogurt

Components%	Whole fat milk
Moisture%	86.16
Protein%	3.55
Fat%	3.70
Total solids%	13.84
Non-fat solids%	10.29
pH	6.64
Titritable Acidity %	0.16
Specific gravity	1.032

Each number in the table represents an average of three replicates

The chemical composition of yogurt fortified with zinc

Table (2) shows the chemical composition of whole milk yoghurt (control C) and yoghurt made from whole milk with zinc at a concentrations of 100 and 200 mg/L represented by T1 and T2 treatments, respectively immediately after manufacture and during storage at (5±1) °C for 14 days.

Moisture percentage : Table (2) shows the percentage of moisture for both the control treatment yogurt (C) and the yogurt treatments T1 and T2 as the value immediately after manufacturing for the control treatment is 86.41% and this result is comparable with Al-Shaikh, (2018) results. The moisture content of zinc-fortified yogurt treatments was 86.46 and 86.41% for the previous treatments, respectively. The results show that there is a slight decrease in the percentage of moisture with the progress of the storage period and for all the treatments of yogurt, which is reached after 14 days for the control treatment 86.14%. Zinc-fortified yogurt treatments were 86.14 and 86.21%, respectively. This decrease may be due to the evaporation rate of moisture content during storage. The results of the statistical analysis indicate that there was no significant differences ($p \leq 0.05$) in the percentage of moisture between treatment C and treatments fortified by zinc immediately after manufacturing, as well as during the storage period of 14 day.

Table 2 : The chemical composition of the control treatment yogurt and the zinc-fortified treatments in two concentrations during storage at a temperature of (5 ± 1) C for 14 days.

Components%						
Moisture%						
Time / Treatments	1	3	5	7	14	**Treatment Mean**
Control	86.41±0.01	86.37±0.01	86.30±0.01	86.29±0.01	86.14±0.01	86.30±0.0960
T1	86.46±0.01	86.39±0.01	86.32±0.01	86.23±0.02	86.14±0.01	86.30±0.118
T2	86.41±0.01	86.37±0.01	86.35±0.03	86.24±0.04	86.21±0.01	86.31±0.0825
Time mean	86.42±0.0265	86.37±0.0132	86.32±0.0274	86.25±0.0361	86.16±0.0361	
LSD TREAT =0.01233	LSD TIME=0.01592	LSD TREAT\ & TIME=0.02757				
Protein%						
Time / Treatments	1	3	5	7	14	**Treatment Mean**
Control	4.15±0.01	4.17±0.01	4.24±0.01	4.26±0.01	4.32±0.01	4.22±0.0645
T1	4.15±0.01	4.19±0.01	4.21±0.01	4.25±0.03	4.30±0.01	4.22±0.0548
T2	4.17±0.01	4.20±0.01	4.21±0.01	4.27±0.01	4.31±0.02	4.23±0.0535
Time Mean	4.15±0.0132	4.18±0.015	4.22±0.0173	4.26±0.0187	4.31±0.0141	
LSD TREAT=0.00943	LSD TIME=0.01218	LSD TREAT & TIME=0.02109				
Fat%						
Time / Treatments	1	3	5	7	14	**Treatment mean**
Control	3.85±0.01	3.88±0.01	3.89±0.01	3.90±0.01	3.96±0.01	3.89±0.0383
T1	3.86±0.01	3.89±0.01	3.89±0.01	3.92±0.01	3.94±0.01	3.90±0.0305
T2	3.89±0.01	3.90±0.01	3.90±0.01	3.94±0.02	3.95±0.01	3.91±0.0261
Time mean	3.86±0.02	3.89±0.0122	3.89±0.00866	3.92±0.0212	3.95±0.0122	
LSD TREAT =0.00794	LSD TIME=0.01025	LSD TREAT & TIME=0.01775				
Lactose%						
Time / Treatments	1	3	5	7	14	**Treatment mean**
Control	4.99±0.01	4.97±0.01	4.95±0.01	4.90±0.01	4.88±0.01	4.93±0.0439
T1	4.92±0.02	4.90±0.01	4.90±0.01	4.90±0.01	4.89±0.01	4.90±0.0142
T2	4.91±0.03	4.89±0.01	4.88±0.01	4.86±0.01	4.82±0.240	4.87±0.351
Time mean	4.94±0.0421	4.92±0.0387	4.91±0.0324	4.88±0.0212	4.86±0.035	
LSD TREAT =0.01019	LSD TIME=0.01315	LSD TREAT & TIME=0.02278				

Ash%						
Treatments \ Time	1	3	5	7	14	Treatment mean
Control	0.60±0.01	0.61±0.01	0.62±0.01	0.65±0.01	0.70±0.01	0.63±0.0383
T1	0.61±0.01	0.63±0.01	0.66±0.01	0.69±0.01	0.71±0.02	0.66±0.0396
T2	0.62±0.02	0.64±0.02	0.68±0.01	0.70±0.01	0.73±0.01	0.67±0.0431
Time mean	0.61±0.015	0.62±0.0180	0.65±0.0278	0.68±0.0245	0.71±0.0180	
LSD TREAT =0.00943		LSD TIME=0.01218			LSD TREAT & TIME=0.02109	

Protein percentage: Table (2) shows the percentage of protein in yogurt treatment C and yogurt fortified by zinc T1 and T2, where immediately after processing for treatment C is 4.15%, while the value of the yogurt fortified by zinc is 4.15 and 4.17% respectively. This finding is consistent with Kahraman and Ustunol, (2012) who reported a slight and non-significant (P <0.05) increase in protein and fat content of zinc-fortified cheese compared to control cheese, while during storage, the percentage of protein in all yoghurt treatments was higher, with values after 14 days for C treatment of 4.32%, and for zinc-fortified treatments were 4.30% and 4.31%, respectively. This finding is agreed with El-Sabie *et al.* (2010) results, who indicated an increase in protein content in yogurt from 4.11 to 44.3% during the 10-day storage period. The results of the statistical analysis indicate no significant differences (P <0.05) in protein percentage between treatment C and zinc-added treatments immediately after processing between all treatments as well as during the 14-day storage period. This indicates that zinc does not affect the protein ratio and this is consistent with Osman and Ismail, (2004) finding.

Fat Percentage: Table (2) shows the percentage of fat in the different treatments mentioned above. The fat in the yoghurt made from whole milk was 3.67%.This finding is consistent with what Sengupta *et al*. (2014) found that the fat content of whole milk yogurt was 3.67%. According to Ahmad (1999), the maximum fat percentage in yoghurt is 4.50, while the fat percentage in yogurt fortified with zinc treatments was 3.89 and 3.86%, respectively. It is noticed at the time of storage that there was an increase in the percentage of fat in the yogurt of all treatments, where the values after 14 days after the manufacture of yogurt treatment C is 3.96% while the yogurt fortified with zinc treatments were 3.94 % and 3.95%, respectively. This increased in fat content may be due to the decrease in moisture content, which led to an increase in the percentage of total solids, including fat. From the results of the statistical analysis, there was no significant differences (<0.05P) in the fat percentage between control C treatment and zinc-fortified treatments immediately after manufacturing and the length of storage period of 14 days, which means that zinc in both concentrations did not affect the fat percentage in the manufactured yogurt. This result is consistent with what El-Din *et al.* (2012) and Aquilanti *et al.* (2012) found when fortifying cheese with zinc and iron salts, and stated that there is no effect of zinc on fat, protein and moisture content as well.

Percentage of carbohydrates: Table (2) shows the percentage of carbohydrates to yogurt of the various treatments mentioned above, which was immediately after the manufacture of yogurt treatment C is 4.99%, this is consistent with what Sengupta *et al*. (2014) found, who indicated that the percentage of carbohydrates to full fat yogurt is 4.47%.The zinc-fortifiedtreatments were 4.92% and 4.91% respectively. The results of statistical analysis indicate that there is no significant differences (P <0.05) in carbohydrate ratio between treatment C and all other treatments immediately after manufacturing, while during storage it is observed that there was a decrease in the percentage of carbohydrates in yogurt all treatments were values after 14 days of manufacturing to the yogurt of the control treatment 4.88%. Zinc-fortified yogurt was 4.89% and 4.82%, respectively. This decrease is due to the activity of the starter bacteria, which convert lactose sugar into lactic acid. This finding is consistent with what Yilmaz-Ersan *et al*., (2014) found, who indicated that the carbohydrate content in yogurt decreased from 4.42% to 4.07% during the 25-day storage period. The results of the statistical analysis indicate that there were no significant differences (P <0.05) in the percentage of carbohydrates between the control treatment and all other treatments during the storage period of 14 days.

Ash percentage: The results shown in Table (2) indicate the percentage of ash in the above-mentioned yoghurt treatments. The ash content immediately after manufacturing for the C treatment was 0.60% and the ash content for the zinc-fortified treatments were 0.61 and 0.62% respectively. As the results of statistical analysis indicate that there is no significant differences (P <0.05) in the ash ratio between the control treatment and the treatments fortified by zinc immediately after manufacturing. While it is noted that there was an increase in the ash percentage with increasing concentration of zinc added. It is also noted from the same table that the ash content at storage at (5 ± 1) ° C increased in all treatments. After 14 days, C values were 0.70%, and the zinc-fortified treatments were 0.71% and 0.73%, respectively. This may be due to loss of moisture content and this is consistent with Kahraman and Ustunol, (2012) results who indicated a slight and non - significant (P <0.05) increase in ash content of zinc - fortified cheese compared with control cheese. The results of the statistical analysis indicate that there was no significant differences (P <0.05) in the percentage values of ash between different time periods within the same treatment.

Physical and rheological properties of zinc-fortified yogurt

Total Titritable Acidity (TA)

The results shown in Table (3) indicate that the total titritable acidity values (calculated on the basis of lactic acid) for the different treatments of yogurt were immediately after manufacture for the treatment of C is 0.83%.This result is similar to that of Nawar *et al*. (2010) for yogurt (0.80%), while the zinc-fortified yogurt treatments were 0.83 and 0.82%, respectively. This finding is consistent with what Oujda El-Sabie *et al.* (2010) finding. We note that there is no effect of zinc on the titritable acidity values of zinc-fortified treatments compared to the control treatment on the first day of manufacture. During storage, an increase in titritable acidity values was observed, which is normal to increase the activity of the starter bacteria and the decomposition of lactose sugar to lactic acid. The values after 14 days for C-treatment were 0.90%, and for the zinc-fortified yogurts were 0.87 and 0.89% respectively. The results of the statistical analysis indicate that there were no significant differences ($p < 0.05$) in the titritable acidity between the control treatment and the yogurt treatments supported by zinc immediately after manufacturing and during the storage period of 14 days.

pH Value

The results shown in Table (2) show the pH values of the various yogurt treatments mentioned above. These values immediately after manufacturing for the C treatment were 4.64, which is consistent with what Al-Shaikh (2018) found to be 4.63 and similar to Santillan-Urquiza *et al.* (2017) result. The pH values of the zinc-fortified yogurt treatments were 4.64 and 4.65, respectively. From the results of the statistical analysis, there is no significant differences ($P<0.05$) in pH values immediately after manufacturing between treatment C and zinc-fortified treatments.At the time of storage, a decrease in pH values was observed for all treatments. After 14 days, the values of C were 4.54 and the zinc-fortified treatments were 4.59 and 4.57, respectively. This is due to the continued activity of the starter bacteria at storage but slowly, this finding is consistent with what Santillan-Urquiza *et al.* (2017) found, indicating a decrease in pH in the control treatment yogurt fortified by zinc nanoparticles from 4.68 to 4.30 during 28 days of storage. It also agrees with Gulbas and Saldamli, (2005), who reported a decrease in the pH values of zinc-fortified cheese after two months of 4.54, compared with the values on the first day of manufacturing of 4.71.The results of the statistical analysis indicate no significant differences ($p < 0.05$) in pH values between the control treatment and the other treatments fortified by zinc during the storage period of 14 days.

Table 3 : Physical and rheological properties of yogurt of control treatment and zinc-fortified treatments in two concentrations during storage at (5 ± 1) °C for 14 days.

Titritable Acidity %						
Time / Treatments	1	3	5	7	14	**Treatment Mean**
Control	0.83±0.0306	0.85±0.00577	0.87±0.02	0.89±0.00577	0.90±0.0153	0.87±0.0305
T1	0.83±0.0153	0.84±0.0115	0.86±0.00577	0.86±0.00577	0.87± 0.01	0.85±0.0173
T2	0.82±0.00577	0.82±0.01	0.84± 0.02	0.87±0.00577	0.89± 0.01	0.85±0.0309
Time mean	0.83±0.0183	0.83±0.0169	0.85±0.0199	0.87±0.0127	0.88±0.0190	
LSD TREAT =0.01025	LSD TIME=0.01323		LSD TREAT& TIME =0.02292			
pH						
Time / Treatments	1	3	5	7	14	**Treatment Mean**
Control	4.64±0.01	4.62±0.00577	4.59±0.01	4.48±0	4.39±0.01	4.54±0.0984
T1	4.64±0.01	4.61±0.01	4.60±0.01	4.56±0.01	4.56±0.01	4.590.0329
T2	4.65±0.01	4.65±0.01	4.59±0.01	4.55±0.02	4.45±0.01	4.57±0.0778
Time Mean	4.64±0.01	4.62±0.02	4.59±0.01	4.53± 0.0394	4.46±0.0752	
LSD TREAT=0.00794	LSD TIME=0.01025		LSD TREAT & TIME=0.01775			
Viscosity						
Time / Treatments	1	3	5	7	14	**Treatment mean**
Control	2262±1	2292±1	2322±1	2490±1	2578±1	2388±127.6
T1	2271±1	2298±1	2348±1	2515±1	2590±1	2404±130.1
T2	2275±1	2301±1	2363±2	2530±1	2600±1	2413±133.2
Time mean	2269±5.831	2297±4.062	2344±18.01	2511±17.52	2589±9.579	
LSD TREAT = 0.817	LSD TIME=1.055		LSD TREAT & TIME=1.827			
Whey Separation						
Time / Treatments	1	3	5	7	14	**Treatment mean**
Control	7.75±0.01	7.31±0.01	7.00±0.01	6.80±0.01	6.50±0.01	7.07±0.446
T1	5.50±0.01	4.97±0.02	4.89±0.01	4.75±0.01	4.10±0.01	4.84±0.469
T2	4.95±0.01	4.56±0.01	4.21±0.01	4.00±0.01	3.85±0.01	4.31±0.413
Time mean	6.06±1.286	5.61±1.285	5.36±1.260	5.18±1.256	4.81±1.269	
LSD TREAT= 0.03918	LSD TIME=0.05058		LSD TREAT & TIME=0.08760			

Viscosity

Viscosity is an important factor in determining the yogurt quality indicators that are related to both product stability and oral taste of fermented milk. Stability of product viscosity is very important for its quality characteristics. According to Rawson and Marshal (1997), Streptococcus Salivarius Subsp thermophilus plays a major role in the production of tissue-giving agents, which are products of the exogenous cell called exopolysaccharides, which may interfere with the protein content of milk and increase its viscosity and improve its quality properties. The results indicated in Table (3) show that the viscosity values of the C treatment immediately after manufacturing were 2262 centipoise, while the viscosity values in the zinc-fortified treatments were 2271 and 2275 centipoise, respectively. The viscosity values of all treatments with storage were observed to increase with the viscosity of the control treatment after 14 days 2578 centipoise. This is consistent with what Shaghaghi *et al*. (2013) found, which indicated that the viscosity of the yogurt treatment increased from 2123 centipoise immediately after manufacturing to 2307 centipoise on day 21 of storage. This may be due to the low pH of yogurt, which increases its hardness and thus increases the viscosity (Walstra *et al.*, 2006). The viscosity of zinc-fortified yogurt treatments were 1490 and 2600 centipoise after 14 days, respectively. This finding is consistent with what he found (El-Sabie *et al.*, 2010) who indicated a significant increase ($P < 0.05$) in the values of zinc-fortified yogurt viscosity of 1232 centipoise. From the results of the statistical analysis, there were significant differences ($P < 0.05$) in viscosity values immediately after manufacturing as well as during storage between treatment C and zinc-fortified treatments.

Drainage of Whey

The drainage of whey in the yogurt is undesirable due to the lack of water held by the protein network, may be due to the lack of solids or because of insufficient heating or pH below 4.4 (Konhorst, 2007). The results show in Table (3) quantities of whey drainage for the various mentioned treatments, which immediately after manufacture for C treatment was 7.75 mL/50 mL and for zinc-fortified yogurt treatments were 5.50 and 4.95 mL/50 mL respectively. This may be due to higher constipation of polysaccharides, which may interfere with the protein content of milk, increase its viscosity and improve its quality properties. We observed that the amounts of whey drainage of zinc-fortified treatments are lower than in C treatment. This finding is consistent with the finding by Achanta *et al*. (2007) which indicated a lower whey drainage rate in zinc-fortified yogurt of 113 ml/300 g compared to a control treatment of 121.67 ml / 300 g. We note that the decrease of whey drainage is increased by increasing the concentration of zinc added. This means that the zinc reduced the exudation, which leads to increased hardness, and increased occasional bonds with the protein network, which increased the strength of the protein network to hold water. The results showed that the amounts of whey drainage were reduced at storage. The values after 14 days of treatment were 6.50 ml/50 ml, and the zinc-fortified yogurt treatments were 4.10 and 3.85 ml/50 ml respectively. This is due to the metabolic activity of the starter bacteria and to the decrease in net pressure inside the protein mold, which reduces the exudation (Guler-Akın and Akın, 2007). The results of the statistical analysis indicate significant differences ($P<0.05$) between the control treatment and the yogurt treatments fortified by zinc immediately after manufacturing and during the storage period for 14 days.

Acid Degree Value (ADV)

Figure (1) shows the degree of fatty decomposition expressed as the acid degree value (ADV) of the various yogurt treatments mentioned above. These values immediately after manufacturing for C were 0.38 ± 0.01 meq / 100 g, which is comparable to the ADV values for T1 treatment with zinc fortified 0.38 ± 0.02 and higher than the T2 treatment of 0.32 ± 0.01 meq/100 g for previous treatments, respectively. It is noted during storage that these values increased as they reached 14 days for the treatment of C is 0.97 ± 0.02 meq/100 g fat. This increase may be due to the activity of lipolytic enzymes originating from either the starter bacteria used for the manufacture of yoghurt or for psychrophilic bacteria that resist high temperatures such as pasteurization and sterilization (McSweeney and Patrick, 2013). While the zinc-fortified yogurt treatments were 0.75 ± 0.02 and 0.69 ± 0.01 meq/100 g respectively. It is clear from these results that the ADV values in the zinc-fortified yogurt treatments after 14 days are less than their value for treatment C, and that decrease is due to zinc and its role in reducing the growth of yogurt-contaminated bacteria. Some research indicates the role of zinc as an antibacterial agent, as well as the role of zinc as an antioxidant, thus preventing oxidative and increasing acidity Yasuyuki *et al.* (2010); Efeovbokhan *et al.* (2014); Jarosz *et al.* (2017); Lee (2018). The results of the statistical analysis also showed significant differences ($P < 0.05$) immediately after manufacturing as well as during the different storage period of 14 days between control treatment and zinc-fortified treatments.

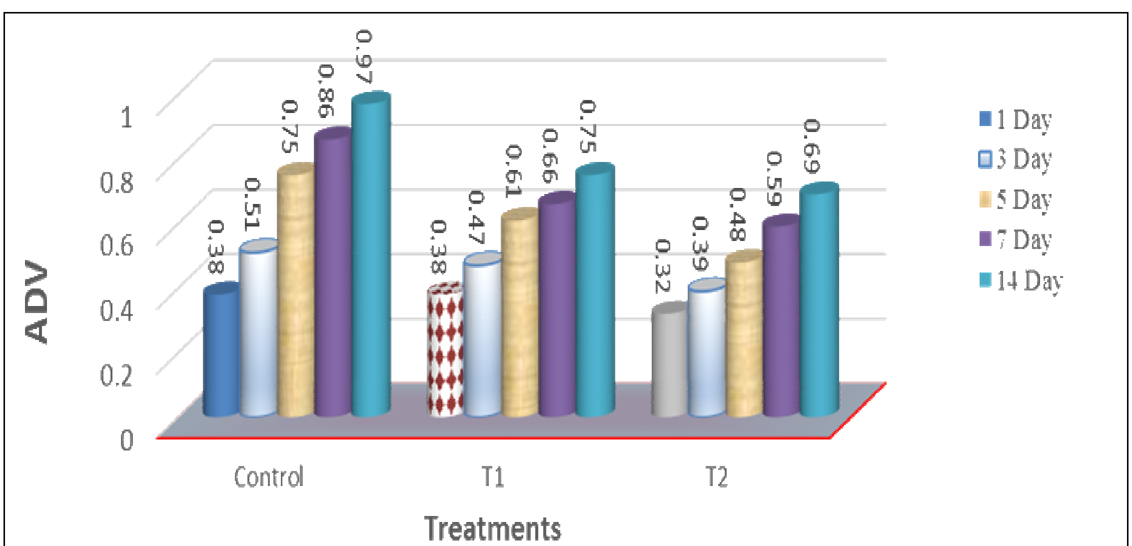

Fig. 1 : The values of ADV for the control yogurt and yogurt fortified by zinc

Peroxide Value (PV)

Figure 2 shows the peroxide values (PV) of the control and zinc-fortified yogurt treatments and the extent of the change in these values. These values immediately after manufacture for C treatment were 0.21 ± 0.01 meq/kg, which is higher than the PV values of the zinc-fortified yogurt treatments of 0.20±0.01 and 0.19 ± 0.01 meq / kg, respectively. We observed an increased in the values when storage for 14 days and the control treatment values were 0.81 ± 0.03 meq/kg, while the zinc-fortified treatments were 0.69 ± 0.01 and 0.59 ± 0.01 meq/kg, respectively. In addition, we note that the PV values in the zinc-fortified treatments are low compared to the treatment of C, which indicates that zinc has an important and effective role in reducing the values of the peroxide and preventing the formation of free radicals. Zinc is an antioxidant known to be involved in the synthesis of the enzyme clotathione peroxidase which plays an important role in protecting alipid tissue from damage caused by free radicals resulting from oxidative stress processes Cortese *et al.* (2008); Wen *et al.* (2019).The results of statistical analysis indicate significant differences (P <0.05) after processing and during storage of 14 days between control treatment and zinc-fortified treatments.

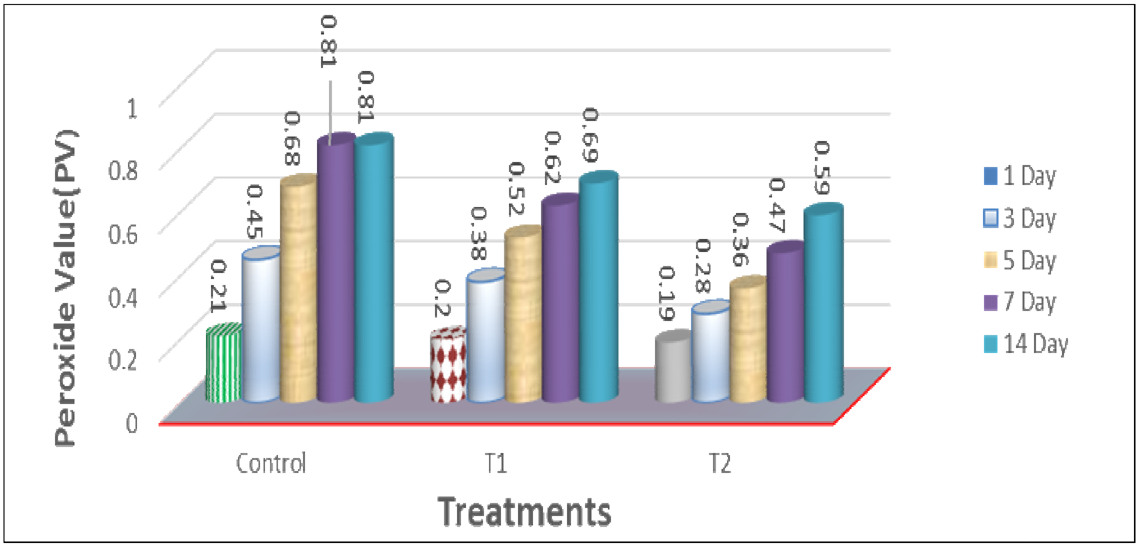

Fig. 2 : The peroxide values for control treatment yogurt and zinc-fortified treatments

Sensory Evaluation

Table (4) shows the results of the sensory evaluation of the various treatments mentioned above, as the results show that the grades of flavor, texture, color, appearance and acidity are higher than that of zinc-fortified treatments compared to the control treatment. This superiority was significant after 1, 3, 5, 7 and 14 days of storage and was attributed to the effect of zinc which improved the sensory qualities of the product. The T1 treatment fortified with 100 mg zinc received the highest total score of 99, 99, 95, 95 and 92 out of 100 on the 1, 3, 5, 7 and 14 days compared with the control treatment that obtained the total grades of 99, 98, 92, 92, 86, while the treatment fortified by zinc at a concentration of 200 mg/L obtained the total grades 99, 97, 91, 88, 85. It is noted from the table that the treatments of yogurt fortified by zinc T1 obtained the highest score of sensory evaluation. This may be attributed to the zinc-catalytic effect on the growth of starter bacteria and the production of acidity and desired flavoring materials, which helped to give a product of good consistency and desirable stiffness, reduced whey drainage and increased water retention. This finding is consistent with what Gulbas and Saldamli (2005) found that zinc-fortified cheese had the highest sensory evaluation of texture, appearance and smell compared to control cheese. The results of the statistical analysis indicate significant differences (P<0.05) between the control treatment and the yogurt treatments fortified by zinc, and significant differences in the sensory evaluation scores between different time periods within the same treatment.

Table 4 : Sensory characteristics of control treatment yogurt and zinc-fortified treatments in two concentrations during storage at a temperature of (5 ± 1) C for 14 days.

Sensory properties						
Flavour (45)						
Time(day) / Treatments	1	3	5	7	14	**Treatment Mean**
Control	44±1	43±1	42±1	42±1	40±1	42.2±1.612
T1	44±1	44±1	43±1	43±1	42±2	43.2±1.320
T2	44±1	43±0	42±0	42±1	41±1	42.4±1.298
Time mean	44.00±0.866	43.33±0.866	42.33±1	42.33±1	41.00±1.5	
LSD TREAT =0.794		LSD TIME=1. 025		LSD TREAT\ & TIME=1.775		

Textures(25)						
Time(day) / Treatments	1	3	5	7	14	**Treatment Mean**
Control	25±0	25±0	22±1	22±1	21±1	23.0±1.852
T1	25±0	25±0	23±1	23±1	23±1	23.8±1.207
T2	25±0	25±0	22±1	22±1	20±0	22.8±2.077
Time Mean	25.00±0	25.00±0	22.33±1	22.33±1	21.33±1.5	
LSD TREAT=0.545		LSD TIME=0.703		LSD TREAT & TIME=1.218		
Appearance(10)						
Time(day) / Treatments	1	3	5	7	14	**Treatment mean**
Control	10±0	10±0	10±0	10±0	9±1	9.8±0.561
T1	10±0	10±0	10±0	10±0	9±0	9.8±0.414
T2	10±0	10±0	9±0	8±1	8±1	9.0±1.069
Time mean	10.00±0	10.00±0	9.667±0.5	9.333±1.118	8.667±0.866	
LSD TREAT =0.3335		LSD TIME=0.4305		LSD TREAT & TIME=0.7457		
Colour(10)						
Time(day) / Treatments	1	3	5	7	14	**Treatment mean**
Control	10±0	10±0	9±1	9±0	8±1	9.2±0.941
T1	10±0	10±0	10±0	10±0	9±0	9.8±0.414
T2	10±0	10±0	9±0	8±1	8±1	9.0±1.069
Time mean	10.00±0	10.000±0	9.33±0.707	9.00±1	8.33±0.866	
LSD TREAT =0.3851		LSD TIME=0.4972		LSD TREAT & TIME=0.8611		
Acidity(10)						
Time(day) / Treatments	1	3	5	7	14	**Treatment mean**
Control	10±0	10±0	9±0	9±1	8±1	9.2±0.941
T1	10±0	10±0	9±1	9±1	9±0	9.4±0.737
T2	10±0	9±0	9±0	8±1	8±1	9.8±0.941
Time mean	10.000±0	9.667±0.5	9.000±0.5	8.667±1	8.333±0.866	
LSD TREAT =0.4716		LSD TIME=0.6089		LSD TREAT & TIME=1.0546		
Total(100)						
Time(day) / Treatments	1	3	5	7	14	**Treatment mean**
Control	99±1	98±1	92±1	92±1	86±2	93.4±4.997
T1	99±1	99±1	95±1	95±3	92±1	96. 0±3.094
T2	99±1	97±0	91±1.732	88±1.732	85±3.464	92.0±5.720
Time mean	99.00±0.866	98.00±1.118	92.67±2.121	91.67±3.536	87.67±3.873	
LSD TREAT =1.218		LSD TIME=1.572		LSD TREAT & TIME=2.723		

References

Bhowmik, D.; Chiranjib, K.P. and Kumar, S. (2010). A potential medicinal importance of zinc in human health and chronic. Int J Pharm, 1(1): 05-11.

FAO/WHO (2004). Expert Consulation on Human Vitamin and Mineral Requirements, Vitamin and mineral requirements in human nutrition: report of joint FAO/WHO expert consolation, 2nd edition. Bangkok, Thailand, 341 pp.

Walingo, M.K. (2009). Indigenous food processing methods that improve zinc absorption and bioavailability of plant diets consumed by the Kenyan population. African Journal of Food, Agriculture, Nutrition and Development, 9(1): 523-535.

Soetan, K.O.; Olaiya, C.O. and Oyewole, O.E. (2010). The importance of mineral elements for humans, domestic animals and plants-A review. African journal of food science, 4(5): 200-222.

Aquilanti, L.; Kahraman, O.; Zannini, E.; Osimani, A.; Silvestri, G.; Ciarrocchi, F. and Clementi, F. (2012). Response of lactic acid bacteria to milk fortification with dietary zinc salts. International dairy journal, 25(1): 52-59.

Santillan-Urquiza, E.; Méndez-Rojas, M.Á. and Vélez-Ruiz, J.F. (2017). Fortification of yogurt with nano and micro sized calcium, iron and zinc, effect on the physicochemical and rheological properties. LWT, 80: 462-469.

Chowanadisai, W.; Kelleher, S. and Lonnerdal, B. (2004). Material zinc deficiency raises plasma prolactin levels in lactating rats. J. Nutr., 134(6): 1314 –1319.

Maret, W. and Sandstead, H.H. (2006). Zinc requirements and the risks and benefits of zinc supplementation. Journal of Trace Elements in Medicine and Biology, 20(1): 3-18.

Ocak, E. and Kose, S. (2010). The effects of fortifying milk with Cu, Fe and Zn minerals on the production and texture of yoghurt. Journal of Food Agriculture and Environment, 8: 122-125.

Lee, S.R. (2018). Critical role of zinc as either an antioxidant or a prooxidant in cellular systems. Oxidative medicine and cellular longevity, 2018.

Hess, S.Y. and Brown, K.H. (2009). Impact of zinc fortification on zinc nutrition. Food Nutr Bul., 30: S79–107.

Clementi, F. (2012). Response of lactic acid bacteria to milk fortification with dietary zinc salts. International dairy journal, 25(1): 52-59.

FDA. Food and drug Administration (2011). Code of Federal Regulations (2011).Title 21, Part 131. Milk and Cream 133. Yogurt, Low Fat Yogurt and Nonfat Yogurt. US Department of Health and Human Services, GMP Publications, Washington, DC. 31–39.

Cheng, H. (2010). Volatile flavor compounds in yogurt: a review. Critical reviews in food Sci. and Nut., 50: 938-950.

Tamime, A.Y. and Robinson, R.K. (1999). Yogurt: Science and Technology, 2nd edn. Boca Raton, FL: CRC Press.

Horwitz, W. and Catimer, G. (2005). Official Methods of Analysis of AOAC International. 18th ed., AOAC International. UAS. Chapter 50: 15-20.

Association of Official Analytical Chemists A.O.A.C. (2008). Official Methods of Analysis 16th ed. Association of Official Analytical Chemists International Arligton, Virginia, U.S.A.

Ling, E.R. (2008). "A textbook of dairy chemistry". Vol. II practical, Chapman and Hall. LTD, (London)

Ihekoronye, A.I. and Ngoddy, P.O. (1985). Integrated food science and technology for the tropics. Macmillan press Ltd London.

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

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

Deeth, H.C. and Fitz-Geraid, C.H. (2004). Lipolysis in dairy products. Aust. J. dairy. Tech., 31: 53-64.

Nelson, J.A. and Trout, G.M. (1964). Judging dairy product. The Olsen Publishing Co., Milwaukee, Wis. 53212, USA.

Genstat (2012). Genstat release 10.3DE. VSN International LTD. Rothamsted Experimental station. UK.

Yilmaz-Ersan, L. and Kurdal, E. (2014). The Production of Set-Type-Bio-Yoghurt with Commercial Probiotic Culture. Int. J. Chem. Eng. and Appl., 5: 402-408.

Al-Shaikh, S.A.H. (2018). Study the effect of fortifying with selenium or physiochemical and sensory properties of the functional yogurt process. Agricultural Sciences, 5(2): 72-90.

Kahraman, O. and Ustunol, Z. (2012). Effect of zinc fortification on Cheddar cheese quality. Journal of dairy science, 95(6): 2840-2847.

El-Sabie, Wafaa, B. and El-Abd, M.M.; Al-Assar, M.A. and Hassan, M.A. (2010). Physicochemical properties of yoghurt fortified with different zinc salts. J. Food and Dairy Sci., Mansoura University, Vol.(11).

Osman, M.M. and Ismail, M.M. (2004). Effect of fortification with zinc, iron and ascorbic acid on the chemical, microbiological and organoleptic properties of buffalo's bio-yoghurt. J. Agric. Sci. Mansoura Univ, 29(1): 237-251.

Sengupta, S.; Ankita, C. and Jayati, B. (2014). Production and evaluation of yogurt with watermelon (*Citrullus lanatus*) juice. J. int. academic research for multidisciplinary. Vol. 2, Issue 5.

Ahmad, M. (1999). Preparation and Evaluation of Fruit Yogurt. M.Sc. (Hones) Thesis, Dept of Food Techno Coll of Agri, Faisalabad University.

El-Din, A.G.; Hassan, A.S.H.; El-Behairy, S.A. and Mohamed, E.A. (2012). Impact of zinc and iron salts fortification of buffalo's milk on the dairy product. W.J. of Dairy & Food Sciences, 7(1): 2.

Aquilanti, L.; Kahraman, O.; Zannini, E.; Osimani, A.; Silvestri, G.; Ciarrocchi, F. and Clementi, F. (2012). Response of lactic acid bacteria to milk fortification with dietary zinc salts. International dairy journal, 25(1): 52-59.

Yilmaz-Ersan, L. and Kurdal, E. (2014). The Production of Set-Type-Bio-Yoghurt with Commercial Probiotic Culture. Int. J. Chem. Eng. and Appl., 5: 402-408.

Nawar, G.A.M.; Fatma, A.M.H.; Ali, K.E.; Jihan, M.K. and Sahar, H.S.M. (2010). Utilization of Microcrystalline Cellulose Prepared from Rice Straw in Manufacture of Yoghurt. J. American Sci., 6: 226-231.

Gulbas, Y. and Saldamli, I. (2005). The effect of selenium and zinc fortification on the quality of Turkish white cheese. Int. J. of food Sci. Nut., 56: 141-146.

Rawson, H.L. and Marschall, V.M. (1997). Effect of 'ropy' strains of *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus thermophilus* on rheology of stirred yogurt. Int. J. Food Sci. Tech., 32: 213-220.

Shaghaghi, M.; Pourahmad, R. and Mahdavi, A.H.R. (2013). Synbiotic Yogurt Production by Using Prebiotic Compounds and Probiotic Lactobacilli. Int. Res J. of Applied Basic Sci., 5(7): 839-846.

Walstra, P.; Wouters, J.T.M. and Geurts, T.J. (2006). Dairy science and technology, 2nd edn. Boca Raton, FL, USA: CRC Taylor and Francis.

Konhorst, A. (2007). The technology of dairy products. Food scince and Technology. U.S.A.

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

Guler-Akın, M.B. and Akınm, S.M. (2007). Effects of cysteine and different incubation temperatures on the microflora, chemical composition and sensory characteristics of bio-yogurt made from goat's milk. Food Chem., 100: 788-793.

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

Yasuyuki, M.; Kunihiro, K.; Kurissery, S.; Kanavillil, N.; Sato, Y. and Kikuchi, Y. (2010). Antibacterial properties of nine pure metals: a laboratory study using *Staphylococcus aureus* and *Escherichia coli*. Biofouling, 26(7): 851-858.

Efeovbokhan, N.; Bhattacharya, S.K.; Ahokas, R.A.; Sun, Y.; Guntaka, R.V.; Gerling, I.C. and Weber, K.T. (2014). Zinc and the prooxidant heart failure phenotype. Journal of cardiovascular pharmacology, 64(4): 393.

Jarosz, M.; Olbert, M.; Wyszogrodzka, G.; Młyniec, K. and Librowski, T. (2017). Antioxidant and anti-inflammatory effects of zinc. Zinc-dependent NF-κB signaling. Inflammopharmacology, 25(1): 11-24.

Lee, S.R. (2018). Critical role of zinc as either an antioxidant or a prooxidant in cellular systems. Oxidative medicine and cellular longevity, 2018.

Wen, M.; Wu, B.; Zhao, H.; Liu, G.; Chen, X.; Tian, G. and Jia, G. (2019). Effects of Dietary Zinc on Carcass Traits, Meat Quality, Antioxidant Status and Tissue Zinc Accumulation of Pekin Ducks. Biological trace element research, 190(1): 187-196.

Cortese, M.M.; Suschek, C.V.; Wetzel, W.; Kröncke, K.D. and Kolb-Bachofen, V. (2008). Zinc protects endothelial cells from hydrogen peroxide via Nrf2-dependent stimulation of glutathione biosynthesis. Free Radical Biology and Medicine, 44(12): 2002-2012.