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Physicochemical Properties of White Soft Cheese Supplemented with Encapsulated Olive Phenolic Compounds

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WHITE soft cheese is one of the most popular, high nutritional, and healthy dairy products in Egypt. The Olive cake and mill waste water are natural sources of phenolic compounds enriched with natural antioxidants. The aim of this work was the use of milk proteins as carriers for olive polyphenolic extract and it uses it in the production of white soft cheese. Polyphenols were extracted from olive mill waste. Maltodextrin (MD) with whey protein isolate (WPI) and skim milk powder (SMP) were used to entrap olive polyphenols extract. Encapsulation efficiency (EE), particle size, zeta potential and electron microscopy for the prepared capsules were assessed. White soft cheese fortified with polyphenol capsules was made. The polyphenols content, antioxidant activity, texture profiles, and sensory properties of cheese were followed. The SMP/MD mixture gives better encapsulation efficiency of 90.08%, while the combination between MD with WPI at ratio 50:50 improved the encapsulation efficiency up to 88.42%. Capsules prepared with the use of SMP/MD mixture less mean diameter of 189 nm compared with using WPI: MD 50:50 which recorded 270.3 nm. Also, capsules prepared with SMP/MD mixture showed zeta potential of -39.75 mV while that prepared using WPI with MD showed -13.7 mV. Electron microscopy revealed that SMP capsules had a diameter of 122.04 nm compared to 262.07 nm for WPI capsules. White soft cheese with fortification by olive polyphenols capsules had high total solids and protein contents and almost constant antioxidant activity during 30 days of cold storage. Hardness, gumminess and chewiness of cheese fortified with polyphenols capsules increased significantly ($P<0.05$) compared to control samples. Also, it gained higher total acceptability scores compared to control. Milk proteins can be used successfully to encapsulate olive polyphenols, and polyphenols capsules can be used in the production of healthy white soft cheese.

Keywords: Milk proteins, Olive polyphenols, Encapsulation, Electron microscopy, White soft cheese, Cheese texture profile.

Introduction

Functional dairy products account for 42.9% of the functional food market [1]. Dairy products have been considered as the most popular delivery vehicles for numerous of functional and healthy ingredients, from vitamin and mineral fortification to addition of bioactives to promote the health benefits of many food products. As milk and dairy products a normal part of our daily diet, in all life stages, any new dairy product

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can be gain some market share. Nowadays the current consumer becomes more interest towards functional products that can decrease the potential risks of diseases [2]**.** Therefore, there is a growing market for foods containing healthy compounds such as phenolic compounds.

White soft cheese production in Egypt accounts for 75% of total cheese production. The use of ultrafiltration (UF) in cheese making offers many advantages, as it increases cheese yield, reduce cost production, the produced has high nutritional and health value as well as solving the problems of whey disposal which produced by the traditional method [3].

International production of olive oil reached about 3 million tons of which. Egypt's production reached about 27 thousand tons during 2016/2017 [4]. Olive oil is the main source of fat in the Mediterranean diet, has been shown to reduce the incidence of age-associated diseases such as cardiovascular, Cancer and Neurodegenerative diseases [5]. Olive oil containing many bioactive compounds including polyphenols, which have been reported to responsible of some health properties of olive oil such as anti-atherogenic, anti-inflammatory, anti-aging, anti-tumor and immune modular activities[6]. The amount of solid waste (leaves and cake) produced from one ton of olive fruits is about 600 kg for three-phase processing system and about 900 kg for two-phase processing system. In other meaning, the olive oil industry in Egypt results in 80 to 90 thousand tons of solid waste [4].

In the last few years, the use of olive cake as a natural source of phenolic compounds has been widely considered. Several studies have focused on the development of new extraction methods for olive polyphenols [7], as well as their use in the production of functional foods enriched with natural antioxidants [8]. In particular, oil-in-water emulsions formulated with stabilizers and enriched with phenolic compounds extracted from olive mill wastewater have recently used in emulsion-based food products with enhanced health properties [9].

Only 2% of its phenolic contents of the fruit are retained in the extracted oil while the remaining is left in the pomace. Therefore, the pomace is considered as a rich source of bio-active ingredients that can be extracted and used as food supplement or in some pharmaceutical applications [10]

Nanocarriers, owing to their high surface area to volume ratio, increased the encapsulation efficiency, improved bioavailability of the encapsulated materials, and offer controlled and sustained release of bioactives [11]. Also, Microencapsulation has been used to protect the probiotic microorganisms against physiological and environmental degradation, and prevent their multiplication in food, with consequent change in sensory properties [12].

Various materials are used as encapsulating agents, especially milk proteins, which exhibit gelifying and emulsifying properties becoming an interesting carrier for microencapsulation of probiotics [13].

The aim of this study was to evaluate the characteristics of UF-white soft cheese fortified with encapsulated olive phenolic compounds.

Materials and Methods

Materials

Imported low heat Skim milk powder (DAIRYAMERICA, Inc**.** CA, USA) was purchased from the local market. The chemical composition of SMP was 34% protein, 51% lactose, 1.2% fat, 8.2% minerals, and 4% moisture as declared by the producer**.** BiPro®, a commercial whey protein isolate (WPI) was obtained as a gift from DavisCo Foods International Inc. (Le Sueur, MN, USA). The WPI was composed of 97.5% proteins and less than 1% lactose as data supplied by producer. Maltodextrin (MD) was obtained from Alfasol Co., Turkey. Milk retentate was obtained from Dairy Industry Unit, Animal Production Research Institute, Ministry of Agriculture, Dokki, Cairo, Egypt. The average composition of milk retentate was 33.38, 13.98 and 14.00% total solids, total proteins and fat contents, respectively.

Olive mill solid waste OMSW was provided by the olive oil industry unit, Food Technology Institute, Ministry of Agriculture, Giza, Egypt. The OMSW was dried in vacuum oven at 40-50°C for 48 h, and then the dried wastes were ground and packed in dark polyethylene bags and kept in refrigerator for further experimentation.

Methanol, ethanol, Folin–Ciocalteau reagent and 2,2-diphenyl-1-picryl- hydrazyl radical (DPPH) were purchased from Merck (Darmstadt, Germany).

Extraction of phenolic compounds

Extraction of phenolic compounds was carried

according to the method described by Zahran and Soliman [14] as follows: five grams from dried olive mill solid waste (OMSWs) were extracted at 18-°C for 20 h. The flasks were then shacked for 90 min before centrifugation at 10000 rpm for 10 min, then, solvent was evaporated from supernatant at 30°C and under vacuum at 100 mbar, and the residue was frozen at -18°C, and then freeze-dried for 24 h. The dried extract was stored in dark bottles at -18°C until analyzed.

Total phenolic contents determination (TPC)

The total phenolic content of the OMSW extracts was determined calorimetrically at 725 nm using the Folin–Ciocalteau reagent according to the method described by Taha et al., [15]. Aliquots of the methanolic of OMSWs extract were diluted with 20 ml of deionized water in a 25 ml volumetric flask and 625 µl of the Folin–Ciocalteau reagent was added. After 3 min, 2.5 ml saturated Na_2CO_3solution (35%) were added. The content was mixed and diluted to volume with deionized water. After 1 h, the absorbance of the sample was measured at 725 nm against a blank using a double-beam ultraviolet–visible spectrophotometer Hitachi U-3210 (Hitachi, Ltd., Tokyo, Japan). Gallic acid served for preparing a standard curve that ranged from 60 to 140 mg mL^{-1}.

Determination of antioxidant activity

Stable 2, 2-diphenyl-1-picryl- hydrazyl radical (DPPH) was used to evaluate the antioxidant activity of OMSWs extract according to method reported by Taha *et al*., [15]. Methanolic solutions of both phenol extracts (0.1 ml) and DPPH (3.9 ml) (0.0025 g/100 ml CH_3OH) were mixed and placed individually in dark and at room temperature for 30 min, by means of a double-beam spectrophotometer (model 2010, Cecil Instr. Ltd., Cambridge, UK), at 517 nm against methanol. Also, a blank sample (0.1 ml methanol + 3.9 ml methanolic solution of DPPH) was measured against methanol at 517 nm. The DPPH radical scavenging activity of the samples was calculated as follow:

DPPH scavenging activity (%) = [(A control – A sample) / A control]

A = absorbance at 517 nm

HPLC Phenolic compounds identification

Separation and quantitative determination of polyphenols content of OMSW extract was carried out by HPLC instrument model 1100 (Agilent Technologies, CA, USA) system column: Agilent Eclipse XDB C18 (150 x4.6 µm 5 µm) according to [16]. The used standards were; gallic Acid, catechin, caffeic acid, rutin, quercetin, cinnamic acid, coumaric acid, ferulic acid, naringenin and propyl gallate.

Microencapsulation of OMSWs Extracts

Microcapsules preparation was done according to the method described by Farrag et al., [17]. Whey Protein isolate (WPI), skim milk (SMP) and maltodextrin (MD) were individually dispersed at 10% (w/v) in de-ionized water and stirred for at least 2 h. at ambient temperature, and then stored overnight at 4°C to ensure complete dissolved. The wall materials, WPI and MD were mixed in ratios 100:0, 75:25 and 50:50 or SMP and MD were mixed in ratio 100:0, 75:25 and 50:50 by gentle magnetic stirring for 1 h. OMSWs extract powder was then added to the wall material at ratio 1:20 and the solution microcapsules was formed using a Magnetic Stirrer (Wisestir MSH-20 D, Korea) for 15 min. Then, mixtures were treated by ultra-sonication at 160 W power, 20 kHz frequency and with 60% pulse (Sonic Vibra cell USA). Then Size, Zeta Potential, and transmission electron microscopy were measured in the liquid sample. The microcapsules were produced solid powder by spray drying the ultrasonicacted mixture using Mini spray dryer, B-290, Buchi, Swisserland.

Size distribution

The z-average diameter and size distribution of entrapped olive polyphenolic compounds (OPC) were carried out at 25 ± 0.1°C using Nano ZS/ ZEN3600 Zetasizer (Malvern Instruments Ltd., UK) with a He / Ne laser (λ = 633 nm), scattering angle 90°. Samples were diluted to obtain a count rate in the appropriate range 100 - 450 nm, transferred into the polystyrene cuvette for size determination, and then the z-average diameter (Dz) and particle dispersity index (PDI) were recorded by dynamic light scattering [18].

Determination of Zeta Potential

The Zeta potential (ζ-potential) of nanoparticles was determined in diluted samples (five folds) by laser Doppler electrophoresis at 25 °C using a Malvern Zetasizer Nano ZS analyzer (Malvern Instruments Ltd., Malvern, UK) and then calculated by the Zetasizer Software.

Encapsulation efficiency

*Total phenolic content of capsules (TPC):*About 100 mg of encapsulated phenolic powder were accurately weighed and dissolved in 1 ml ethanol/acetic acid/water mixture (50:8:42),

[19]. This mixture was agitated using Vortex (Vortex V1 plus BoECo. Germany) for 1 min and filtered through Whatman filter paper No. 1. Total phenolic content was measured by the modified Folin-Ciocalteu method as described above. The total phenolic content of freeze-dried phenolic powder was expressed as Gallic acid equivalents (GAE) in milligrams per gram dry weight.

Surface phenolic content of capsules (SPC):

For the determination of SPC, the method of Bae and Lee [19] was followed one hundred mg of microcapsules were dispersed with 1 ml of ethanol and methanol mixture (1:1, v/v) for 1 min. The amounts of surface phenolic compounds were measured and quantified with the same previous method described in TPC section.

Encapsulation efficiency:

The encapsulation efficiency (EE) is the ratio of encapsulated phenolic content to TPC. Encapsulated phenolic content (EPC) is determined by taking the difference of Total phenolic content(TPC) and surface phenolic content of capsules (SPC). Encapsulation efficiency of microcapsules was calculated according to equation:

$$EE = \frac{TPC - SPC}{TPC} \times 100$$

Characteristic microstructure

Samples of encapsulated olive phenolic extract were prepared for transmission electron microscopy (TEM) by fixation with glutaraldehyde as described by McClements, [20]and then diluted (1:100 v/v) with deionized water. A drop of diluted suspension was placed on the format-coated electron microscopy grid, left for 1 min and then a drop of phosphotungstic acid solution (2% at pH 7.2) was added. The grid was air dried and examined by TEM using a JEOL JEM-1400 plus TEM with an accelerating voltage of 100 kV at a magnification of 200,000 x.

Cheese manufacture:

Milk retentate was salted with 3% table salt (NaCl). Freeze-dried olive polyphenol extract and encapsulated polyphenols in WPI: MD (50:50) and in SMP was added to separated portions of milk retentate to fortify the retentate with 100 mg phenolic compounds / 100 g retentate. The retentate without added phenolic compounds (control) and phenolic fortified retentates from the different treatments were heated at 72°C for 30 sec and then cooled immediately to 42°C, and made into cheese as described by Farrag *et al***.** [21]. Cheese from different treatments was stored at refrigerator temperature at (5 ± 2°C) for 30 days. Three replicate were prepared from the different treatment and control.

Cheese analysis:

The cheese samples were analyzed for moisture and fat contents as described by AOAC [22]. Total nitrogen as described in IDF standard [23]. The pH value was measured using a HANNA laboratory pH meter with glass electrode.

Texture profile of white soft cheese:

The Texture Profile Analysis (TPA) of white soft cheese was performed using multi test 1-d texture analyzer, (mecmesin limited, Slinfold, West Sussex, UK) according to the method of Farrag *et al*., [24]. Experiments were carried out by a compression test that generated a plot of force (N) versus time (sec). Samples were double compressed at a compression speed of 2 cm/min. The analysis was carried out at room temperature. Hardness (N), springiness (mm), chewiness (N*mm), gumminess (N) and cohesiveness were calculated from the obtained TPA according to the definition given by the International Dairy Federation [23]

Sensory evaluation:

The UF soft cheese fortified with polyphenol capsules were scored for organoleptic properties by experts judges and consumers from a 15 members of Dairy Department, National Research Centre as described by Farrag et al., [24]. The panelists scored the cheese for flavour (out of 50 points), body and texture (out of 35points) and appearance (out of 15 points).

Statistical analysis:

The values of the means were statistically analyzed by SPSS computer software (version 17.0). The calculation occurred by analysis of variance one way ANOVA and followed by TUKEY honestly test, according to Steel *et al.*, [25].

Results and Discussions

Chemical composition of OMSWs extract is shown in Table 1. OMSW containing 46.26% moisture and 28.86 mg/g dry weight total phenolic contents. The antioxidant capacity (IC_{50}) of OMSW extracts was 17.42 ± 1.24µg mL^{-1}.

HPLC analysis of OMSW extract showed

the presence of polyphenols as shown in Table 2. Querectin recorded highest contents of 957.96µg/g. Other polyphenols recorded 603.35, 348.31, 294.65 and 45.62 µg/g of Propyl Gallat, rutin, syringic acid and coumaric acid respectively.

Encapsulation Efficiency

The effects of the different wall material types on the encapsulation efficiency are illustrated in Fig. 1. The use SMP as wall material gave the highest encapsulation efficiency (EE) of 90.08%, while EE with the use WPI as wall material recorded 73.04%. Incorporation of maltodextrin (MD) with WPI improved the EE which increased to 77.62 and 88.42% at ratios of 75:25 and 50:50 WPI: MD respectively. The combination between WPI with MD can reduce the cost of encapsulation, avoided particles agglomeration due to the low hygroscopicity of MD, which can enhance the surface characteristics of the obtained microcapsules [26]. Maltodextrin was reported to improve encapsulation efficiency due to their high solubility, low viscosity, and good gel formation properties [27].These results could be attributed to the possible interaction between whey proteins

TABLE 1: Gross Composition and antioxidant activity of OMSW extract.

Parameters	Value*
Moisture (%)	46.26 ±3.50
Oil (%)[a]	13.30 ± 1.50
pH	5.6 ±0.30
Total phenol content (mg/g dry weight)	28.86 ± 0.036
Antioxidant capacity (IC_{50}) of OMSW extracts (µg mL-1)	17.42 ±1.24

** = Mean ± SD,[a] = Oil content calculated on dry weight basis*

TABLE 2: Theprofiling of phenolic compounds for OMSWs Extracts by HPLC

Compounds	Area	Conc. (µg/g)
Coffeic Acid	33.01	25.68
Syringic Acid	295.78	294.65
Rutin	188.32	348.31
Coumaric Acid	86.81	45.62
Querectin	454.60	957.96
Cinnamic Acid	89.65	21.74
Propyl Gallate	852.29	603.35

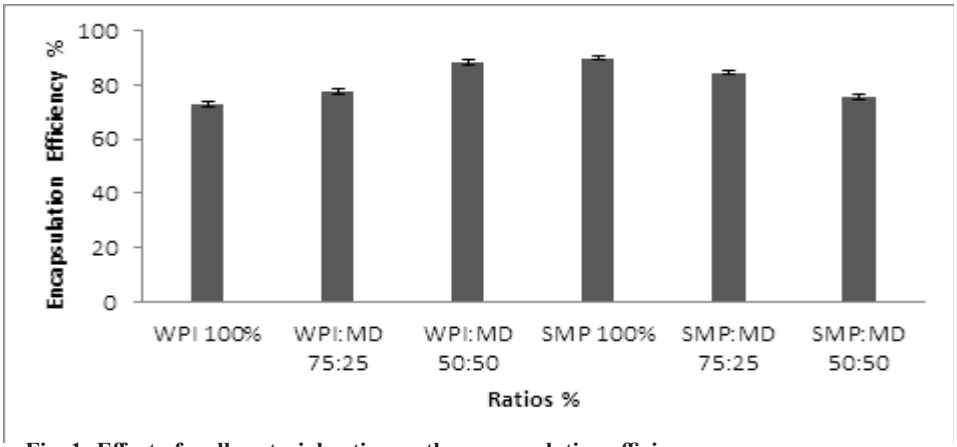


Fig. 1: Effect of wall material ratios on the encapsulation efficiency.

and maltodextrin to form colloidal matrix capable for better encapsulation of polyphenols. On opposite, addition of MD to SMP decreased the EE to 84.70 and 75.67% at SMP: MD at ratios of 75:25 and 50:50 respectively. The results confirm that the addition of MD to WPI improved the WP efficiency as a carrier vehicle of polyphenols constituents. Our finding was agreed with that reported by Farrag et al., [17].

Particle Size:

Droplet size, mean diameter D32, of entrapped olive polyphenolic compounds (OPC) increased in the presence of MD with WPI or SMP as shown in table 3.The use of WPI as encapsulation matrix resulted in higher mean diameter compared with using SMP. The mean diameter D32 increased from 222.9 nm with 100% WPI to 244.3 and 270.3 nm when mixed with MD at ratios of 75:25 and 50:50 respectively. On the other hand, the mean diameter of particles based on the use SMP was 189.5 nm which increased to 216.6 and 258.8 nm at 75:25 and 50:50 SMP: MD ratios respectively. The presence of insufficient or excess of emulsifier in the aqueous solution could lead to different droplet size of the obtained emulsions [28].

Di Mattia et al., [29] reported that the increase in droplet size of O/W emulsion depends on the type of phenolic compounds used, and their possible changes in the protein rearrangements.

Zeta Potential:

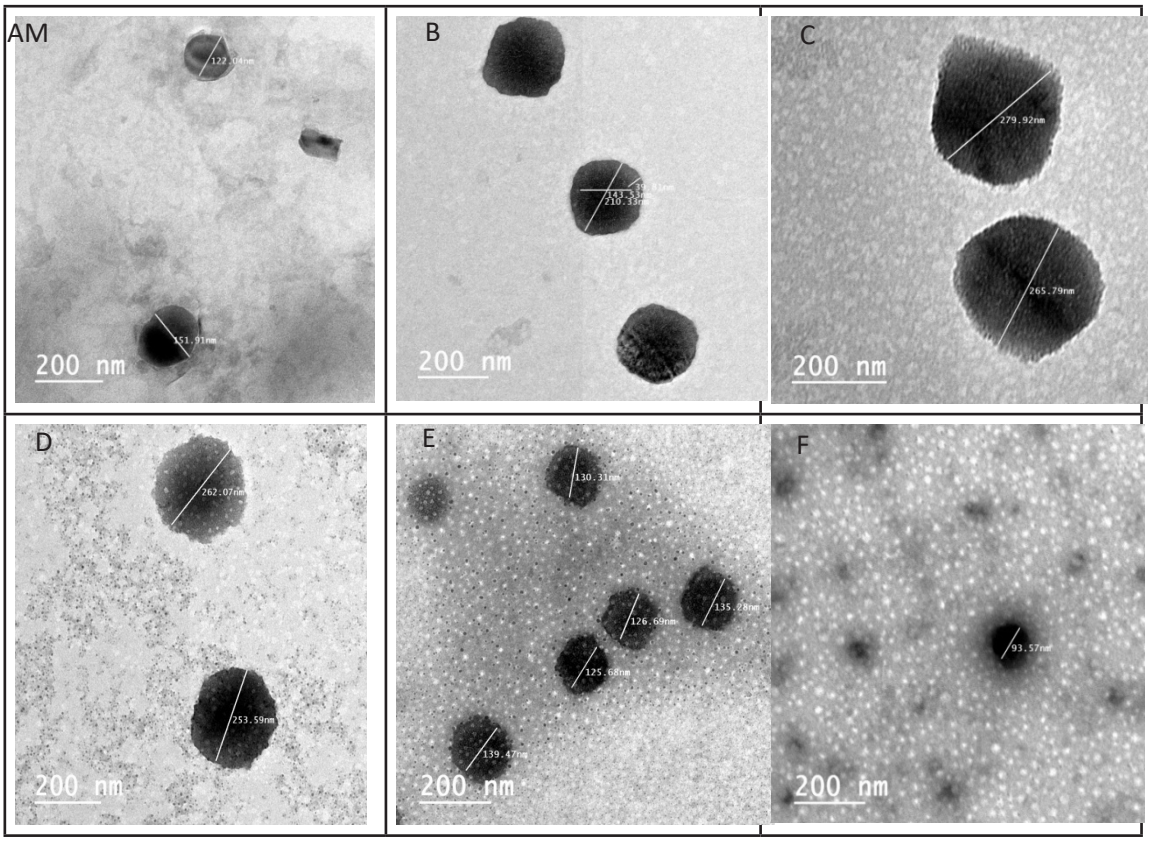
The potential distance exists between the particle surface and the dispersing liquid, this potential is called the Zeta potential [30]. Zeta potentials of the stabilized emulsions were determined to follow the surface charge of olive polyphenols capsules which refer to predictive of the colloidal emulsion stability (Table 3). The SMP as coat material resulted in particles of -39.75 mV zeta potential while using WPI gave particles of -13.7 mV. The stability of emulsions was reported to be depended on the strong interfacial film [31]. Nanoparticles with zeta potential values greater than positive 30 mV or less than negative 30 mV had high degrees of stability [32].

Electron Microscopy

Transmission electron microscope (TEM) can provide detailed microscopic structure, and the crystalline state of the samples. Figure 2 illustrate the TEM images of olive polyphenol microcapsules. The images illustrate remarkable differences depending on the wall material used. Generally the outer surface of the different particles was characterized by irregular shape, absence of cracks, little of cavities and small particle sizes. These properties are a common morphology for polymer particles prepared by spray drying due to the formation of a polymeric layer on the particle surface at the early stages of drying, followed by shrinkage due to removal of the water [33].The results cleared that the using SMP only as wall materials gave small capsules particle diameter compared with using WPI as carrier vehicle. SMP gave particle capsules with diameter of 122.04 to 151.91 nm compared to 253.59 to 262.07 nm for capsules prepared from WPI. Incorporating (MD) with WPI improved encapsulation process and resulted in smaller particles. Addition of MD to WPI at the ratio of 75:25 led to decrease in the average particle size to 135.28 nm and further decreased to 93.57 nm at WPI: MD ratio of 50: 50. Unlike, the particle diameter increased to 279.92 nm with incorporated MD with SMP at the ratios 50:50.These results agree with that reported by Farrag *et al*., [17].

TABLE 3: Particle size, Zeta potential and Polydispersity Index of olive polyphenol capsules as affected by wall material composition

Treatment	Particle Size D_{32}(nm)	Zeta potential (mV)	Calculated PDI
loaded 20mg/ g wall			
WPI 100%	222.9^{b}	-13.7^{b}	0.182^{b}
WPI 75 %-MD 25%	244.3^{c}	-4.34^{d}	0.304^{d}
WPI 50%-MD50%	270.4^{d}	-10.70^{c}	0.425^{e}
SMP 100%	189.5^{a}	-39.75^{a}	0.228^{bc}
SMP 75 %-MD 25%	216.6^{b}	-10.5^{c}	0.256^{c}
SMP 50 %-MD 50%	258.8^{c}	-13.3^{b}	0.099^{a}



A: SMP, B: 75%SMP + 25% MD, C: 50%SMP + 50% MD, D: WPI, E: 75% WPI + 25% MD, F: 50% WPI + 50% MD

Fig. 2: TEM images of olive polyphenol microcapsules.

Cheese pH development:

Developments of white soft cheese pH are shown in Table 4. No significant differences were found in the pH fresh cheese from different treatments which ranged from 6.64 to 6.71. Cheese with added free polyphenol extract showed the lowest pH of 5.99 after 30 days of storage. Cheese supplemented with olive polyphenols capsules had pH values a linear similar to the control indicating that the encapsulation additive did not interfere with the normal acid development of cheese during storage.

Cheese composition:

The chemical composition of fresh white soft cheese fortified with polyphenols capsules is shown in Table 5. The results cleared that the total solids and total protein contents were higher with cheese samples fortified by olive polyphenols capsules. These the total solids of control cheese was 37.84% and were 42.99 and 43.03% for cheese fortified with polyphenols capsules with WPI: MD 50:50% and SMP polyphenols capsules, respectively. Also, total protein increased to 16.45% and 15.85% in cheese fortified Polyphenols capsules with WPI: MD 50:50% and SMP, respectively. These increases in both total solids and total proteins may be due to the added solids and proteins from the used wall materials. The cheese from control and that fortified with free and capsules had the same fat content exact ranged from 13.00 to 13.78%. Similar trend was found by Farrag *et al*., [24].

Cheese phenolic contents

The total phenolic contents of white soft cheese are shown in Fig. 3. Polyphenols content decreased significantly from 112.35 to 78.95 mg/100 g cheese after 30 days of storage in the cheese fortified with free olive polyphenols extract. On the other hand, cheese fortified with encapsulated polyphenols using WPI: MD 50:50 and SMP wall material retained almost constant level of polyphenols when fresh and after 30 days storage being 125.36 and 125.95 and 123.96 and 123.87 mg/100g respectively. This means that the polyphenols encapsulation was powerful to keep the polyphenolics contents from degradation or oxidation during cheese storage. El-Messery et al., [34] reported that the polyphenolics contents increased in the yoghurt fortified with encapsulated polyphenols during cold storage up to 15 days.

TABLE 4: pH development of white soft cheese

Treatment	Fresh	After 30 days
Control	6.71[a]	6.33[b]
polyphenols extract	6.64[a]	5.99[a]
Polyphenols capsules with WPI : MD 50:50%	6.69[a]	6.45[b]
Polyphenols capsules with SMP 100%	6.69[a]	6.37[b]

TABLE 5: Chemical composition of fresh white soft cheese fortified with encapsulated polyphenols.

Treatment	TS	TP	Fat
Control	37.84[a] ± 0.59	14.89[a] ± 0.23	13.65[a] ± 0.50
polyphenols extract	37.97[a] ± 0.76	14.78[a] ± 0.52	13.60[a] ± 0.10
Polyphenols capsules with WPI : MD 50:50%	42.99[b] ± 0.92	16.45[c] ± 0.49	13.00[a] ± 0.50
Polyphenols capsules with SMP 100%	43.03[b] ± 0.84	15.85[b] ± 0.62	13.75[a] ± 0.15

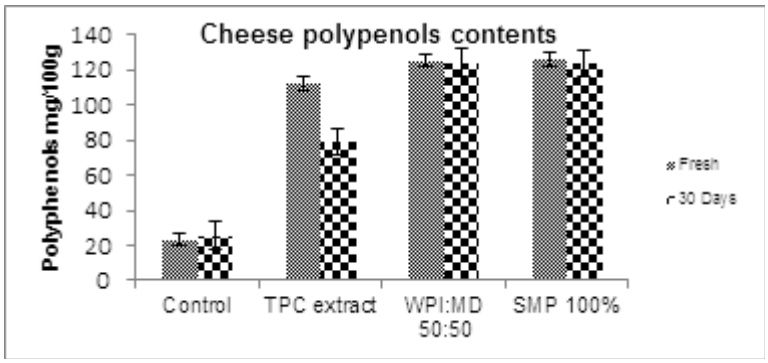


Fig. 3: Polyphenolics contents of soft cheese during storage.

Cheese antioxidant activity

Cheese fortified with polyphenols capsules recorded highest antioxidant activity of 77.25 and 76.10% after 30 days for WPI: MD 50:50 and SMP wall material, respectively as shown in Fig. 4. On the contrary, antioxidant activity of cheese fortified with free polyphenols extract decreased from 85.35 to 52.12% after 30 days of cold storage. These can be explained by the susceptibility of the free polyphenolics to oxidation and degradation during storage [35, 36]**.**

Cheese Texture Profile

Texture profile of white soft cheese fortified with olive polyphenols are presented in table 6. Hardness of fresh cheese increased significantly from 12.4 to 17.00 and 17.90 (N) with the addition encapsulated polyphenols with WPI: MD 50:50% and SMP, respectively. Springiness and Cohesiveness showed negligible differences results even in fresh or stored cheese samples. Fresh cheese gumminess values increased significantly of 7.27, 11.62 and 12.41 (N) for cheese samples fortified with free polyphenol, and encapsulated polyphenols with WPI : MD 50:50% and SMP, respectively. Also, chewiness of fresh cheese increased with fortification by olive polyphenols from 4.57 to 7.41 and 8.80 N/mm, in the same order. These differences can be attributed to the use of WPI/MD or SMP as wall materials in the encapsulation process. This wall material increased in the total solids and protein contents at resulted cheese. Similar observations were reported by Farrag et al., [21].No significant

changes occurred after 30 days of cold storage for all cheese texture attributes.

Sensory evaluation

Sensory attributes indicated that the fresh soft cheese fortified with uncapsulated polyphenols extract got the lowest scores compared to other treatments as shown in Table 7. Cheese fortified with encapsulated polyphenols gained higher total scores of 95.64 and 95.75 for polyphenols capsules with WPI: MD 50:50% and SMP, respectively. The fortification of cheese with polyphenols capsules SMP 100% wall material had improved both body & texture and flavour which recorded of 34.25 and 47.45 in the same order. These results coincide in the same trend with those obtained by Farrag *et al*., [21].

Conclusions

Milk proteins can be used successfully as wall material of high encapsulation efficiency for olive polyphenols. The use of SMP as coating material gives better encapsulation efficiency of 90.08%. Mixture of WPI and MD (50:50) improved the encapsulation efficiency of WPI from 73.04 to 88.42%. UF-white soft cheese can be fortified matrix with encapsulation polyphenols in SMP or WPI: MD (50:50) as wall material. Cheese fortified with polyphenols capsules gained higher total scores and got better flavor, body & texture and acceptability. Polyphenols capsules can be considered beneficial in the production of healthy and functional white soft cheese.

Acknowledgments

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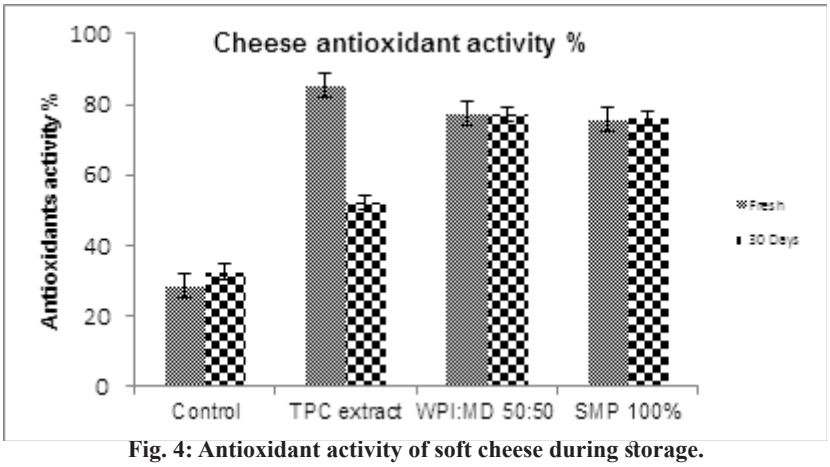

Fig. 4: Antioxidant activity of soft cheese during storage.

TABLE 6: Texture attributes of UF- white soft cheese fortified with olive polyphenols.

Test / Treatment	Hardness (N)		Springiness (mm)		Cohesiveness		Gumminess (N)		Chewiness (N*mm)	
	Fresh	30 Days	Fresh	30 Days	Fresh	30 Days	Fresh	30 Days	Fresh	30 Days
Control	12.40^{a}	12.60^{a}	0.70^{b}	0.63^{a}	0.69^{b}	0.66^{b}	8.53^{a}	8.27^{a}	6.00^{b}	5.17^{b}
polyphenols extract	12.20^{a}	12.30^{a}	0.63^{a}	0.60^{a}	0.60^{a}	0.57^{a}	7.27^{a}	7.07^{a}	4.57^{a}	4.23^{a}
Polyphenols capsules With WPI : MD 50:50%	17.00^{b}	17.30^{b}	0.64^{a}	0.65^{ab}	0.68^{b}	0.69^{bc}	11.62^{b}	11.93^{b}	7.41^{c}	7.81^{c}
Polyphenols capsules With SMP 100%	17.90^{b}	18.20^{b}	0.71^{b}	0.71^{b}	0.69^{b}	0.71^{c}	12.41^{b}	12.98^{b}	8.80^{d}	9.20^{d}

Means in the same column and superscript are not significant differences (p>0.05)

TABLE 7: Sensory evaluation of fresh white soft cheese fortified with olive polyphenols.

Test/Treatment	Appearance (15)	Body and texture (35)	Flavour (50)	Total score (100)
Control	14.00[b]	33.87[b]	46.88[a]	94.75[b]
polyphenols extract	13.25[a]	32.75[a]	46.78[a]	92.78[a]
Polyphenols capsules With WPI : MD 50:50%	13.97[b]	34.17[b]	47.32[b]	95.46[b]
Polyphenols capsules With SMP 100%	14.05[b]	34.25[b]	47.45[b]	95.75[b]

Means in the same column and superscript are not significant differences ($p>0.05$)

References

1. Watson E., Carvalho A., Green R., Britton S, and Scott S. Functional ingredients. *Food Manufacture,* **81**(11), 4–19, (2006).
2. Hélène M., Champagne C.P., Gelais ST., Brittein D.M., Fustier M., Lacroix P.M. Effect of time of inoculation, starter addition, oxygen level and salting on the viability of probiotic cultures during cheddar cheese production. *International Dairy Journal*, **21**(1), 75-82, (2011).
3. Coker C.J, Crawford R.A., Johnson K.A., Singh H., and Creamer L.K. Towards the classification of cheese variety and maturity on the basis of statistical analysis of proteolysis.A review *International Dairy Journal*, **15**, 631-643, (2005).
4. International Olive Council (IOC), 2017. World Olive Oil Figures. [ONLINE] Available at: *http://www.internationaloliveoil.org/estaticos/view/131-world-olive-oil-figures*.[Accessed 2017].
5. López-Miranda J., Pérez-Jiménez F., Ros E., De Caterina R., Badimón L., Covas M.I., Escrich E., Ordovás J.M., Soriguer F., Abiá R., et al., Olive oil and health: Summary of the II international conference on olive oil and health consensus report, Jaén and Córdoba (Spain) 2008. *Nutrition Metabolism Cardiovascular.***20**, 284–294, (2010).
6. 6- Fitó M., De la Torre R., Covas M. I. Olive oil and oxidative stress. *Molecular Nutrition & Food Research*, **51,** 1215–1224, (2007).
7. Venturi F., Sanmartin C., Taglieri I., Andrich G., Zinnai A. A simplified method to estimate Sc-CO_2 extraction of bioactive compounds from different matrices: Chili pepper vs. tomato by-products. *Applied science*, **7**, 361,(2017).
8. Caporaso, N., Formisano, D. and Genovese, A., Use of phenolic compounds from olive mill wastewater as valuable ingredients for functional foods. *Critical reviews in food science and nutrition*, **58**(16): 2829-2841, (2018).
9. Caporaso N., Genovese A., Burke R., Barry-Ryan C., Sacchi R. Physical and oxidative stability of functional olive oil-in-water emulsions formulated using olive mill wastewater biophenols and whey proteins. *Food Function*, **7,**227–238, (2016).
10. Suárez M., Romero M.P., Ramo T., Macià A., and Motilva M.J. Methods for preparing phenolic extracts from olive cake for potential application as food antioxidants. Journal of Agricultural and *Food Chemistry*, **57**, 1463-1472, (2009).
11. Jafari, S.M. and McClements, D.J.,. Nanotechnology approaches for increasing nutrient bioavailability. *In Advances in food and nutrition research.Academic Press,* **81**, 1-30,(2017).
12. Kent R. M., and Doherty S. B., Probiotic bacteria in infant formula and follow-up formula: Microencapsulation using milk and pea proteins to improve microbiological quality. *Food Research International,* **64,** 567-576, (2014).
13. Doherty S. B., Gee V. L., Ross R. P., Stanton C., Fitzgerald G. F., and Brodkorb A. Development and characterisation of whey protein micro-beads as potential matrices for probiotic protection. *Food Hydrocolloids,* **25**(6), 1604-1617, (2011).
14. Zahran H.A., and Soliman H.M. UPLC-Q-TOF/MS screening of bio-active compounds extracted from olive mill solid wastes and their effect on oxidative stability of purslane seed oil. *Current Science International*, **7**(2), 307-319, (2018).

15. Taha F.S., Wagdy S.M., Hassanein M.M., and Hamed S.F. Evaluation of the biological activity of sunflower hull extracts. *Grasas y aceites*.**63**(2):184-92, (2012).

16. El-Kholy W.M., Soliman T.N., and Darwish A.M. Evaluation of date palm pollen (Phoenix dactylifera L.) encapsulation, impact on the nutritional and functional properties of fortified yoghurt. *PloSOne*, **14**(10), 1-23, (2019).

17. Farrag A. F., El-Messery T. M., El-Said M.M., Soliman T.N., and Fakhr El-Din H. Microencapsulation of grape phenolic compounds using whey proteins as a carrier vehicle. *Journal of Biological Science*, **18**(7), 373-380, (2018).

18. Carneiro H.C.F., Tonon R.V., Grosso C.R.F., and Hubinger M.D. Encapsulation efficiency and oxidative stability of flaxseed oil microencapsulated by spray drying using different combinations of wall materials, *Journal Food Engineering*, **115**, 443-451, (2013).

19. Bae E. K. and Lee S.J. Microencapsulation of avocado oil by spray drying using whey protein and maltodextrin. *Journal Microencapsulation*, **25**, 549-560, (2008).

20. McClements, D. J. Theoretical Analysis of Factors Affecting the Formation and Stability of Multilayered Colloidal Dispersions. *Langmuir*, **21** (21), 9777- 9785, (2005).

21. Farrag A.F., El-Sheikh, M. M., Tawfeek M. F., Sayed A. F., and Abd El-Aziz, M. Properties of Probiotic UF-white Soft Cheese Fortified with Garlic Extract. *Journal of Biological Science*, **19** (1), 65-73, (2019).

22. AOAC,.Official Methods of Analysis. 16th Edn.,*Association of Official Analytical Chemists*, Washington, DC., USA,(2000).

23. IDF, Rheological and fracture properties of cheese. *Bulletin of the International Dairy Federation* No. 268/1991, Brussels, Belgium, 1-67, (1991).

24. Farrag A.F., Bayoumi H.M., Ibrahim W.A., El-Sheikh M.M., and Eissa H.A. Characteristics of White Soft Cheese Fortified with Hibiscus Soft Drink as Antimicrobial and Hypertension Treatment. *International Journal of Dairy Science*, **12** (2), 122-129, (2017).

25. Steel R.G.D., Torrie J.H., Dickey D.A. Principles and procedures of statistics: *A biometrical approach, 3rd Edition.* New York, USA: McGraw Hill, (1997).

26. Anekella K., and Orsat V. Optimization of microencapsulation of probiotics in raspberry juice by spray drying. LWT - Food Science and Technology, **50**(1), 17-24, (2013).

27. Mahdavi A.S., Jafari S.M., Assadpoor E., Dehnad D. Microencapsulation optimization of natural anthocyanins with maltodextrin, gum Arabic and gelatin. *International Journal of Biological Macromolecules*, **85**, 379–385, (2016).

28. McClements D. J. Food emulsions: principles, practices, and techniques: CRC press (2015).

29. Di Mattia C., Sacchetti G., Mastrocola D., Sarker D. K., and Pittia P. Surface properties of phenolic compounds and their influence on the dispersion degree and oxidative stability of olive oil O/W emulsions. *Food Hydrocolloids*, **24**(6), 652-658, (2010).

30. Martin A., Physical Pharmacy, IVth ed., *Lippincott Williams and Wilkins*, New York, 2001, 486-494, (2001).

31. Patil, S., Sandberg A., Heckert E., Self W., and Seal S. Protein adsorption and cellular uptake of cerium oxide nanoparticles as a function of zeta potential. *Biomaterials,***28** (31), 4600–4607, (2007).

32. Kumar, A. and Dixit, C.K., Methods for characterization of nanoparticles. In Advances in Nanomedicine for the Delivery of Therapeutic Nucleic Acids (pp. 43-58). *Woodhead Publishing*, (2017).

33. Zhang S., and Kawakami K. One-step preparation of chitosan solid nanoparticles by electrospray deposition.*International Journal of Pharmaceutics*, **397**, 211–217, (2010).

34. El-Messery T.M., El-Said M.M., Shahein N. M., Fakhr El-Din H., and Farrag A.F. Functional yoghurt supplemented with extract orange peelencapsulated using coacervation technique. *Pakistan Journal of Biological Sciences*, **22** (5), 231-238, (2019).

35. Mohamed F.A., Salama H.H., El-Sayed S.M., El-Sayed H.S., Zahran H.A., Utilization of natural antimicrobial and antioxidant of Moringaoleifera leaves extract in manufacture of cream cheese. *Journal of Biological Science*,**18**(2), 92-106, (2018).

36. Soliman, T.N., Farrag, A.F., Zahran, H.A.H. and El-Salam, M.E.H.A., Preparation and Properties Nano-encapsulated Wheat Germ Oil and its Use in the Manufacture of Functional Labneh Cheese. *Pakistan Journal of Biological Sciences*, **22**(7), 318-326, (2019).