OPEN ACCESS Journal of Biological Sciences

ISSN 1727-3048
DOI: 10.3923/jbs.2019.

Research Article
Effect of *Spirulina platensis* as Nutrition Source on the Chemical, Rheological and Sensory Properties of Spreadable Processed Cheese

[1]M.M. Tohamy, [2]Hamdy A. Shaaban, [1]M.A. Ali and [1]A.M. Hasanain

[1]Department of Dairy Science, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt
[2]Department of Chemistry of Flavour and Aroma, NRC, 33 El Bohouth St. Dokki, P.O. Box 12622, Dokki, Cairo, Egypt

Abstract

Background and Objective: Supplementation of conventional foods with *Spirulina platensis* seems to be promising trend due to the nutritional value of such alga which is known as a rich source of protein, fatty acids, fiber, essential vitamins and minerals. Also, it have a functional properties due to the presence of anti-oxidants, omega 3, anti-viral and anti-cancer components. Therefore, the aim of the present study was to supplement processed cheese with *Spirulina platensis* in order to enhance the nutritional and health value of the final product. **Materials and Methods:** Processed cheese analog (PCA) was supplemented with 2, 4 and 6% of *Spirulina platensis* on powder form and 4% of this alga on slurry form. The chemical, rheological and sensory properties were evaluated for supplemented PCA as fresh and within 3 months of cold storages 5-7°C. **Results:** Supplemented PCA with 2% of algae showed the best sensory properties followed by 4% fortified sample, but the level of 6% was unacceptable. The chemical analysis of supplemented PCA showed an increase in the contents of protein, ash, fiber, selenium, zinc, iron, magnesium and potassium. Anti-oxidants activity was higher in supplemented PCA in comparison to control sample. With respect to the powder form of algae, application of slurry form improved more the organoleptic, physical and rheological properties of PCA properties. **Conclusion:** Supplemented PCA with *Spirulina platensis* proved to have excellent nutritional, functional and healthy properties to be used as nutraceutical food.

Key words: Spreadable processed cheese, *Spirulina platensis*, chemical composition, rheological characteristics, sensory properties

Received: Accepted: Published:

Citation: M.M. Tohamy, Hamdy A. Shaaban, M.A. Ali and A.M. Hasanain, 2019. Effect of *Spirulina platensis* as nutrition source on the chemical, rheological and sensory properties of spreadable processed cheese. J. Biol. Sci., CC: CC-CC.

Corresponding Author: Hamdy Shaaban, Department of chemistry of Flavour and Aroma, NRC, 33 El Bohouth St. Dokki, P.O. Box 12622, Dokki, Cairo, Egypt
Tel: 00201143399059 Fax: +2-02-33370931

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Processed cheese represented one of the most important dairy products that is popular owing to likeable savor and distinctive texture with easily produced and handled. Processed cheese is produced by blending natural cheese of different ages and degrees of maturity in the presence of emulsifying salts and other dairy and non-dairy ingredients followed by heating and continuous mixing to form a homogeneous product with an extended shelf life[1,2]. The development of process cheese was brought about by Kraft 1916 in US, when it preserved natural cheese in cans by heating and mixing it in order to increase its shelf life[3]. Later, new varieties of processed cheese were invented using non-conventional additives e.g., peppers, spices, mushroom, sausage, oat olives and meats and production of smoked processed cheese etc. The nutritional and potential therapeutic value of food is a key characteristic in the development of new value added products that are manufactured for health conscious consumers like people that suffer from certain diseases such as heart disease or hardening of the arteries[4-6].

Algae are an enormous biological resource, representing one of the most promising sources to enhance the nutritional value of food and animal feed, due to their well-balanced chemical composition[7]. The application of microalgae biomass and/or metabolites is an interesting and innovative approach for the development of nutraceutical food products[8]. Some microalgae species e.g., *Chlorella* sp. and *Spirulina* sp. have been used for many centuries as a nutrient-dense food in Asia, Africa and Mexico. However commercial large-scale production of microalgae only started in the early 1960s (Japan) and nowadays microalgae are mainly marketed as food supplements, commonly sold in the form of tablets, capsules or liquids. Additionally, there is an increasingly growing market for food products with microalgae addition such as pastas, biscuits, mayonnaise, bread, snack foods, candy bars or gums, yoghurts, drink mixes, soft drinks, etc.[9].

Spirulina platensis is a species of filamentous cyanobacteria that grows naturally in alkaline salt lakes. It has a high protein, vitamins such as A, B2, B6, B8, B12, E and K, anti-oxidant components, abundant amino acids, iron, calcium and unsaturated fatty acids. It has functional properties e.g., anti-cancer, antiviral, antitumor, reduces blood lipid pro le, blood sugar, body weight and wound healing time[10-12].

The aim of this research is increment of nutritional and potential therapeutic value of processed cheese by using *spirulina platensis* algae in powder and slurry forms because of its high nutritional and health value. Evaluation the effect of supplementation by this alga on chemical, physical, rheological and sensory properties of the processed cheese within 3 months of cold storage (5-7°C) was also studied.

MATERIALS AND METHODS

Materials: Matured cheddar cheese (6 months old) was imported from New Zealand by Khaled Khoshala Co. for Food Industries and Cooling, Egypt. Ras cheese (1 month old) was obtained from Mariam Co., Giza, Egypt. The Fonterra butter was obtained from Sakr Group Co., Egypt. Low heat skim milk powder was from Irish Dairy Board (Grattan House, Lower Mount St., Dublin, Ireland). Kasomel (K-2394) and Joha S4 emulsifying salts were obtained from Rhone-Poulenc Chimie, France. *Spirulina platensis* biomass in the forms of freeze-dried and slurry were obtained from Algal Biotechnology Unit (National Research Centre, Dokki, Cairo, Egypt). Table 1 showed the chemical composition of the ingredients used in manufacture of processed cheese analogue.

Methods

Preparation of algae: Clean growth was performed within 1200 L Zigzag photo-bioreactor according to El-Sayed[13] in the presence of the growth media as described by El-Sayed *et al.*[14]. For harvesting and cleaning of the obtained biomass a series of precipitation and washing was performed using tap water and cooling centrifuge (Heidelberg Runne, RSU-20).

Manufacture of processed cheese analogue (PCA): The PCA was manufactured as described by Savello *et al.*[15] with 50-55% moisture and 48-50% fat-in-dry-matter. PCA treatments were

Table 1: Chemical composition (%) of the ingredients used in manufacture of processed cheese

	Ingredients					
Analysis (%)	Cheddar cheese	Ras cheese	Butter	Skim milk powder	*Spirulena platensis* (powder)	*Spirulena platensis* (Slurry)
Total solids	65.80	54.81	84.00	96.00	93.67	11.2
Fat	34.80	24.77	81.99	0.97	8.03	0.96
Crude protein	[1]25.47	[1]22.26	[2]ND	[1]37.13	[3]59.79	[3]7.15
Ash	5.42	5.76	ND	7.89	8.40	1.00
Carbohydrate	0.10	1.64	ND	47.43	15.01	1.79
Fiber	ND	ND	ND	ND	2.44	0.29

1: Protein %-N×6.38, 2: ND, 3: protein% - N × 4.38

manufactured by partial replacing of the base cheeses (Ras and Cheddar) with 2, 4 and 6% of *Spirulina platensis* in powder form and with 4%in slurry form (Table 2). Processed cheese and PCA were prepared by blending the dry ingredients with previously warmed (50°C) butter at the pilot plant unit of the National Research Centre. Cooking was done using direct injection of steam at pressure of 1.5 bar to 66°C with continuous agitation for 4 min. The blends were further heated to a final temperature of 82°C in approximately 4 min and kept isothermal for 1 min to add the algae, prior to filling into tin cans then stored at 5-7°C.

Methods of analysis: *Spirulena platensis* nutrient profile was determined by AOAC[16] standard methods in terms of moisture, ash, protein, fat and fiber contents, while total carbohydrate content were calculated by difference. Total solids, fat content, titratable acidity, soluble nitrogen and total protein content for control and supplemented processed cheese were determined as described by Ling[17]. Meanwhile, the ash and salt contents were determined according to the method by AOAC[16] and Bradley *et al.*[18]. The pH values were measured using a laboratory digital pH meter model Adwa 1030. Minerals were detected and quantified using atomic absorption spectrophotometer (model: GBC932AA) at the Regional Centre for Food and Feed, Agricultural Research Center, Giza. Vitamins content were determined at National Research Center as mention by De Leenheer and Lambert[19]. Anti-oxidants activity was determined at National Research Center according to Hatano *et al.*[20] with some modifications. Oiling off was determined according to the method outlined by Thomas[21]. Meltability of the sample of processed cheese was determined according to the method designed by Olson and Price[22] and slightly modified by Savello *et al.*[15]. Texture properties of PCAs were analyzed by universal testing machine device described by Bourne[23].

Table 2: Formulations of different processed cheese analogue with dried *Spirulena platensis* (kg/100 kg)

		Treatments (%)		
Ingredients	Control	2	4	6
Cheddar cheese	12.8	12.8	12.8	12.8
Ras cheese	38.44	36.09	35.53	34.92
Skim milk powder	5.12	4	3	2
Butter	10.26	10.26	10.26	11
Salt	-	0.1	0.2	0.3
Emulsifying salt (K-2394)	2.5	2.5	2.5	2.5
Spirulena platensis	-	2	4	6
Water	30.88	32.25	31.71	30.48
Total	100	100	100	100

Organoleptic properties evaluation: All samples of processed cheese were evaluated organoleptically for the different sensory properties using a hedonic scale of 1-5, which was designed by Larmond[24]. The sensory evaluation was carried out by the staff members of the Dairy Department, Al-Azhar University.

RESULTS AND DISCUSSION

Effect of adding dried *Spirulina platensis* on the processed cheese properties: Sensory evaluation for processed cheese with/without Algae: Data in Table 3 presented the results of adding 2, 4 and 6% of algae on sensory properties of the processed cheese. The processed cheese with 2% of *S. platensis* showed identical properties in terms of the spreading quality, saltiness, flavor, gumminess and overall preference followed by supplemented sample with 4% of *S. platensis* algae, while the sample with 6% addition of *S. platensis* was rejected organoleptically. On the basis of the above results, further investigation was only carried out for the products with 2 and 4% addition of *S. platensis* algae.

Chemical analysis of studied processed cheese: The results of the chemical analysis presented in Table 4 indicated that,

Table 3: Sensory evaluation of processed cheese supplemented with *Spirulina platensis*

		Processed cheese made using *Spirulina platensis*			Score limit	
Attribute	Control	2%	4%	6%	1	5
Surface appearance	3	2.5	3	4	Dull very much	Shiny very much
Firmness of body	2	2	2.5	3	Very soft	Very firm
Spreading quality	3	3	4	4	Difficult to spread	Easy to spread
Stickiness	3	2	2	1	Not sticky	Very sticky
Smoothness of texture	4.5	3	2.5	2	Not smooth	Very smooth
Breakdown properties	4	2	2	1.5	Doesn't dissolves	Dissolve very well
Oiling off	1	1.5	2	3	Absent	Very pronounced
Flavour	3	3	3.5	4	Very weak	Very strong
Saltiness	3	3	3	3	Not salt	Very salt
Over all preference	4.5	4	3	2	Dislike very much	Like very much

Table 4: Chemical composition of processed cheese supplemented with *Spirulina platensis*

		Spirulina platensis cheese (%)	
Analysis (%)	Control	2	4
Fat	19.5	20.5	21.0
T.S	39.73	41.62	42.97
F/DM	47.82	49.3	48.9
Salt	1.19	0.962	0.993
SN	1.03	0.852	0.977
TP	12	13.05	13.46
Ash	2.26	3.76	3.77
Fiber	0.00	0.14	0.21

Table 5: Changes in pH during storage for processed cheese supplemented with *Spirulina platensis*

		Spirulina platensis cheese (%)	
Storage periods	Control	2	4
Fresh	5.77	5.90	5.92
1 month	5.72	5.86	5.88
2 months	5.70	5.80	5.82
3 months	5.67	5.71	5.75

Table 6: Changes in acidity during storage of processed cheese supplemented with *Spirulina platensis*

		Spirulina platensis cheese	
Storage period	Control	2	4
Fresh	1.4	1.3	1.2
1 month	1.5	1.4	1.3
2 months	1.7	1.6	1.5
3 months	1.8	1.7	1.6

the addition of algae to the processed cheese had increased the fat content slightly from 19.5% for the control sample to 20.5 and 21% for the processed cheese samples with 2 and 4% of *S. platensis* respectively. With respect to the higher protein content of *S. platensis* (Table 1), the supplemented processed cheese with 4% of algae exhibited the highest TP level (13.46%) compared to the control sample (12%) as obtained by Toro *et al.*[25] and Mohamed *et al.*[26]. Supplementation with *S. platensis* increased the fiber content of the processed cheese samples (Table 4). Fiber is an important ingredient to reduce risk of degenerative diseases including diabetes, obesity, coronary heart disease, bowel cancer and gallstones[27]. The addition of algae to the processed cheese has increased the ash content of the final product. The highest level of ash was 3.77% for processed cheese fortified with 4% of *S. platensis*, while the lowest level was in the control sample (2.26%) which was in agreement to Shalaby and Yasin[28].

The pH level and acidity of supplemented cheese: The results in Table 5 indicated that the pH level had increased on storage as the percentage of added algae increased. This was may be due to the pH value of algae themselves which range between[29] 8.5-11. As the duration of storage at 7°C was increased, the pH value was noticed to decrease which could be attributed to acidity increase of the fortified cheese samples (Table 6) and conforming to report of Seleet *et al.*[30] and Mehanna *et al.*[31].

Table 7: Minerals content of processed cheese supplemented with *Spirulina platensis*

	Treatments	
Elements (mg kg^{-1})	Control	*Spirulina platensis* cheese (4%)
Selenium	2.494	17.00
Zinc	0.410	13.25
Iron	6.938	27.184
Magnesium	172.7	192.90
Calcium	3954	3979.00
Potassium	463.9	832.90

Minerals content in the processed cheese supplemented with *Spirulina platensis*: Selenium was found at 17 mg kg^{-1} for the processed cheese fortified with 4% of *S. platensis* as compared to the control sample (2.494 mg kg^{-1}) while zinc was 13.25 mg kg^{-1} (Table 7). Devi *et al.*[32] reported that zinc is important for the human body to care for the skin, teeth, bones, hair, nails, muscles, nerves and the brain function. The body uses zinc to heal wounds and pneumonias addition to its support for body growth. The *S. platensis* has added substantial level of iron content to the processed cheese recorded at 27.184 mg kg^{-1} compared to only 6.938 mg kg^{-1} for the control sample. Iron is one of the main body nutrients forming hemoglobin in the blood red cells as well as myoglobin that distributes oxygen all over the body in addition to storing oxygen in the muscles and tissues[33].

Spirulina platensis cheese sample showed a high content of magnesium at 192.9 mg kg^{-1} compared to 172.7 mg kg^{-1} for the control sample. Magnesium is another important element that the body uses to regulate the transfer of nerves signal, nerves connectivity, muscles contraction, blood pressure and the insulin metabolism. It also plays an important role in the care of many diseases such as Alzheimer, insulin resistance, diabetes, high blood pressure and heart and blood vessels disorders such as brain attack and migraines as reported by Grober *et al.*[34]. As for calcium, the fortified cheese samples did not show any significant increase in its content.

Results showed higher content of potassium which was reported at 832.9 mg kg^{-1} for supplemented sample compared to 463.9 mg kg^{-1} for the control one. Lanham-New *et al.*[35] reported that taking high doses of potassium have a positive effect against many problems that affect the heart system, the kidneys, the bones and the blood vessels. Continuous dosages of potassium reduce the blood pressure and are also effective in reducing the risks of brain stroke and preventing chronic kidney damage.

Table 8: Changes in melting index during storage of processed cheese

		Spirulina platensis cheese (%)	
Time under cooling	Control	2	4
Fresh	57	78	130
1 month	57	79	140
2 months	58	80	146
3 months	60	83	150

Table 9: Changes in oiling off during storage of supplemented processed cheese

		Spirulina platensis cheese (%)	
Time under cooling	Control	2	4
Fresh	40	44	51
1 month	46	56	58
2 months	50	60	62
3 months	54	68	70

Spirulina platensis has antioxidant properties as indicated by the *in vitro* and *in vivo* studies. The protective effect of algae against CCl_4-induced liver toxicity is due to free radical scavenging. This observation is attributed to its high contents of proteins, lipids, minerals (zinc, manganese, magnesium and selenium) and some vitamins (beta carotene, riboflavin, cyanocobalamin, alfa-tocopherol and alfa-lipoic acid)[36].

Meltability of supplemented processed cheese: The Table 8 presented the relationship between meltability of the processed cheese and the effect of adding algae at zero time and during storage period at 5-7°C. The addition of algae to the processed cheese had increased the degree of the meltability when compared with the control sample at both zero time and during storage. Mohamed *et al.*[37] reported that the degree of meltability of the processed cheese could be affected by the ingredients of the products, and/or the increased rigidity and reduced flowing rate could be attributed to the reduction of the fat granules size. Meanwhile, Solowiej[38] found out that the viability of fusion is related to the increase in pH value along with smoothness in the texture, high degree of the disintegration of casein and the reduction of fat emulsification. The soft texture of the processed cheese together with an increase in the moisture content could also leads to increased meltability.

Oiling off: The degree of oiling off in the studied processed cheese had been recorded in Table 9. While the control sample indicated the lowest degree of oiling off especially at the zero time in comparison with supplemented samples (2 and 4% of *S. platensis*). Saad *et al.*[39] mentioned that the low degree of oiling off could be attributed to the high stability of the emulsified material and the good fat emulsification in the texture. During the storage of the processed cheese, all products showed gradual increase in the degree of oiling off proportional to the storage duration. Bachmann[40] pointed out that the increase in oiling off could be due to the existence of another protein other than casein in the processed cheese mixture, makes the cheese less capable to keep the protein inside with the fat in the emulsion and this is more likely to take place as the storage period is increased. This explained the increase of oiling off in the supplemented cheese products as they contain small portions of algae protein and hence less capable of keeping the fat as in the case of the casein of the milk.

Table 10: Supplemented processed cheese with 4% of *S. platensis* in slurry form

Ingredients	Control	Supplemented formula (%)
Cheddar cheese	12.80	12.80
Ras cheese	38.44	38.44
Skim milk powder	5.12	5.00
Butter	10.26	10.26
Salt	-	0.20
Emulsifying salt S4	1.70	1.70
Spirulena platensis	-	4.00
Water	30.88	27.40
Total	100.00	100.00

Effect of adding slurry *Spirulina platensis* on the processed cheese properties: *Spirulina platensis* was studied in the form of slurry for manufacturing analog processed cheese. S4 emulsifying salt was tested in the supplemented sample in order to improve oiling off and meltability of the final product as shown in Table 10. Emulsifying salts are of major importance in processed cheese production where they were used to provide a uniform structure during the melting process and supplement the emulsifying capability of cheese proteins. This was accomplished by removing calcium from the protein system and peptizing, hydrating, swelling, solubilizing and dispersing the protein. In addition, it emulsified fat to stabilize the emulsion, controls pH and formed an appropriate structure after cooling[41].

Sensory evaluation for processed cheese with/without Algae: The Table 11 presented the results of adding 4% of slurry algae on the sensory properties of the processed cheese. Using of algae in slurry form apparently improved the sensory properties of the supplemented cheese. The granular texture completely disappeared in cheese made by using slurry of algae and this could be inferred through the degrees of arbitration smoothness of texture in Table 10. Also, oiling off was absent in samples due to use emulsifying salt (S4).

Chemical analysis of the supplemented cheese: Result in Table 12 showed that, in comparison to control sample, total

Table 11: Sensory evaluation of processed cheese supplemented with slurry *S. platensis*

Attributes	Control	Processed cheese with *S. platensis*	Score limit	
			1	5
Surface appearance	4	4	Dull very much	Shiny very much
Firmness of body	3	3	Very soft	Very firm
Spreading quality	3	4	Difficult to spread	Easy to spread
Stickiness	3	3	Not sticky	Very sticky
Smoothness of texture	5	4	Not smooth	Very smooth
Breakdown properties	4	4	Doesn't dissolves	Dissolve very well
Oil separation	1	1	Absent	Very pronounced
Flavour	5	4	Very weak	Very strong
Saltiness	3	3	Not salt	Very salt
Over all preference	5	4	Dislike very much	Like very much

Table 12: Chemical analysis of processed cheese supplemented with slurry *S. platensis*

Ingredients	Control	Processed cheese with *S. platensis*
TS	50.63	48.93
Fat	25.60	24.5
Ash	3.08	3.28
pH	5.49	5.81

Table 13: Rheological Properties of processed cheese made by using slurry algae

Rheological properties	Control	*Spirulina platensis* cheese
Oiling off (%)	10	10
Melting index (mm)	95	80
Penetrometer reading (mm)	76	82

solids and fat content were lower in supplemented sample. While ash content increased in fortified sample. The pH value of cheese sample made by using algae in slurry form was higher than control one, 5.81 and 5.49 in algae cheese and control samples in table 11, respectively.

Rheological properties of the supplemented cheese: Table 13 showed the rheological properties; Oiling off, Meltability and Penetrometer degrees of analog processed cheese. The control and supplemented cheese samples had the same rate of oiling off (10%). Meltability of supplemented cheese sample was lower than the control one. The cheese sample fortified with algae was higher than the control sample for penetrometer reading, 76 and 82 mm in control and fortified respectively.

CONCLUSION

This study has highlighted the nutrition value of *Spirulina platensis* with higher contents of fiber, elements, vitamins and anti-oxidants that may use to formulate nutraceutical food products. Also, its can additionally enhance the rheological properties of the fortified processed cheese.

SIGNIFICANCE STATEMENT

Since the use of algae in processed cheese is still on a very small scale, this study was of importance to the applicability with a product that is not easy to get. To maintain the characteristics of processed cheese after adding algae which will be difficult to obtain otherwise. Addition of 2% of the *Spirulina platensis* in soft powder form can keep the sensory properties and improve the nutritive characteristics of the final product, while using 4% of the algae in slurry form can additionally enhance the rheological properties of the fortified processed cheese. Return the importance and usefulness of this study for its role at the industry level and health.

REFERENCES

1. Guinee, T.P., M. Caric and M. Kalab, 2004. Pasteurized Processed Cheese and Substitute/Imitation Cheese Products. In: Cheese: Chemistry, Physics and Microbiology, Volume 2: Major Cheese Groups, Fox, P.F., P.L.H. McSweeney, T.M. Cogan and T.P. Guinee (Eds.). 3rd Edn., Elsevier Press, Beiging, ISBN: 978-0-12-263653-0, pp: 349-394.
2. Hladka, K., Z. Randulova, B. Tremlova, P. Ponizil, P. Mancik, M. Cernikova and F. Bunka, 2014. The effect of cheese maturity on selected properties of processed cheese without traditional emulsifying agents. LWT-Food Sci. Technol., 55: 650-656.
3. Kapoor, R. and L.E. Metzger, 2008. Process cheese: Scientific and technological aspects-A review. Comprehen. Rev. Food Sci. Food Saf., 7: 194-214.
4. Fernandez-Garcia, E., J.U. McGregor and S. Traylor, 1998. The addition of oat fiber and natural alternative sweeteners in the manufacture of plain yogurt. J. Dairy Sci., 81: 655-663.
5. Fathi, F.A., G.A.M. Hussein and A.G. Mohamed, 2005. Fortification of processed cheese spread with accustomed edible mushroom. Arab Univ. J. Agric. Sci., 13: 825-839.

6. Fox, P.F., T.P. Guinee, T.M. Cogan and P.L. McSweeney, 2017. Processed Cheese and Substitute/Imitation Cheese Products. In: Fundamentals of Cheese Science, Fox, P.F., P.L.H. McSweeney, T.M. Cogan and T.P. Guinee (Eds.)., Springer, oston, MA., pp: 589-627.
7. Pulz, O. and W. Gross, 2004. Valuable products from biotechnology of microalgae. Applied Microbiol. Biotechnol., 65: 635-648.
8. Gouveia, L., A.P. Batista, A. Raymundo and N. Bandarra, 2008. *Spirulina maxima* and *Diacronema vlkianum* microalgae in vegetable gelled desserts. Nutr. Food Sci., 38: 492-501.
9. Abd El-Razik, M.M. and A.G. Mohamed, 2013. Utilization of acid casein curd enriched with *Chlorella vulgaris* biomass as substitute of egg in mayonnaise production. World Applied Sci. J., 26: 917-925.
10. Smieszek, A., E. Giezek, M. Chrapiec, M. Murat, A. Mucha, I. Michalak and K. Marycz, 2017. The influence of *Spirulina platensis* filtrates on Caco-2 proliferative activity and expression of apoptosis-related microRNAs and mRNA. Mar. Drugs, Vol. 15, No. 3. 10.3390/md15030065
11. Zeinalian, R., M.A. Farhangi, A. Shariat and M. Saghafi-Asl, 2017. 2017. The effects of *Spirulina platensis* on anthropometric indices, appetite, lipid profile and serum Vascular Endothelial Growth Factor (VEGF) in obese individuals: A randomized double blinded placebo controlled trial. BMC Complement. Altern. Med., Vol. 17, No. 1. 10.1186/s12906-017-1670-y
12. Troschl, C., K. Meixner and B. Drosg, 2017. Cyanobacterial PHA production-review of recent advances and a summary of three years' working experience running a pilot plant. Bioengineering, Vol. 4, No. 2. 10.3390/ bioengineering4020026
13. El-Sayed, A.B., 2011. Photo-bioreactor for algae production and carbon dioxide consumer. Egyptian Patent, Under Reviewing, 1283/2011.
14. El-Sayed, A.B., F.E. Abdalla and A.A. Abdel-Maguid, 2001. Use of some commercial fertilizer compounds for *Scenedesmus* cultivation. Egypt. J. Phycol., 2: 9-16.
15. Savello, P.A., C.A. Ernstrom and M. Kalab, 1989. Microstructure and meltability of model process cheese made with rennet and acid casein. J. Dairy Sci., 72: 1-11.
16. AOAC., 2006. Official Methods of Analysis. 18th Edn., Association of Official Analytical Chemists Inc., Arlington, TX., USA.
17. Ling, E.F., 1963. A Text Book of Dairy Chemistry: Vol. 2, Practical. 3rd Edn., Chapman and Hall Ltd., London, pp: 58-65.
18. Bradley, Jr. R.L., E. Arnold Jr., D.M. Barbano, R.G. Semerad, D.E. Smith and B.K. Vines, 1993. Chemical and Physical Methods. In: Standard Methods for the Examination of Dairy Products, Marshall, R.T. (Ed.). 16th Edn., American Public Health Association, Washington, DC., USA., ISBN-13: 978-0875532103, pp: 433-529.
19. De Leenheer, A.P. and W. Lambert, 2000. Modern Chromatographic Analysis of Vitamins: Revised and Expanded. Vol. 84. CRC Press, New York.
20. Hatano, T., H. Kagawa, T. Yasuhara and T. Okuda, 1988. Two new flavonoids and other constituents in licorice root: Their relative astringency and radical scavenging effects. Chem. Pharm. Bull., 36: 2090-2097.
21. Thomas, M.A., 1973. The use of a hard milkfat fraction in processed cheese. Aust. J. Dairy Technol., 28: 77-80.
22. Olson, N.F. and W.V. Price, 1958. A melting test for pasteurized process cheese spreads. J. Dairy Sci., 41: 999-1000.
23. Bourne, M.C., 2002. Food Texture and Viscosity: Concept and Measurement. 2nd Edn., Academic Press, New York, USA., ISBN-13: 9780121190620, Pages: 427.
24. Larmond, E., 1977. Laboratory Methods for Sensory Evaluation of Food. (Canada Department of Agriculture Publication Series No. 1637). Canada Department of Agriculture, Ottawa.
25. Toro, E.E.B., J.U.S. Valencia and D.A.R. Molina, 2016. Characterization of a processed cheese spread produced from fresh cheese (Quesito antioqueno). Rev. Fac. Nac. Agron. Medellin, 69: 8015-8022.
26. Mohamed, A.G., T.A. Morsy, S.M. Kholif and F.A.M. Hassan, 2013. Nutritive value of processed cheese manufactured from goat's milk fed diet supplemented with essential plant oils. World Applied Sci. J., 26: 1400-1406.
27. Alvarez, M.D., C. Fernandez, M.D. Olivares and W. Canet, 2012. Comparative characterization of dietary fibre-enriched frozen/thawed mashed potatoes. Int. J. Food Prop., 15: 1022-1041.
28. Shalaby, S.M. and N.M.N. Yasin, 2013. Quality characteristics of croissant stuffed with imitation processed cheese containing microalgae *Chlorella vulgaris* biomass. World J. Dairy Food Sci., 8: 58-66.
29. Falquet, J. and J. P. Hurni, 1997. The nutritional aspects of *Spirulina*. Antenna Technologies, Switzerland.
30. Seleet, F.L., J.M. Kassem, H.M. Bayomim, N.S. Abd-Rabou and N.S. Ahmed, 2014. Production of functional spreadable processed cheese analogue supplemented with chickpea. Int. J. Dairy Sci., 9: 1-14.
31. Mehanna, N.S., F.A.M. Hassan, T.M. El-Messery and A.G. Mohamed, 2017. Production of functional processed cheese by using tomato juice. Int. J. Dairy Sci., 12: 155-160.
32. Devi, C.B., T. Nandakishore, N. Sangeeta, G. Basar, N.O. Devi, S. Jamir and M.A. Singh, 2014. Zinc in human health. IOSR J. Dental Med. Sci., 13: 18-23.
33. Jackson, A., 2010. Iron and health. Department of Health, The Stationery Office, London. https://www.tsoshop.co.uk/.
34. Grober, U., J. Schmidt and K. Kisters, 2015. Magnesium in prevention and therapy. Nutrients, 7: 8199-8226.
35. Lanham-New, S.A., H. Lambert and L. Frassetto, 2012. Potassium. Adv. Nutr., 3: 820-821.

36. Hoseini, S.M., K. Khosravi-Darani and M.R. Mozafari, 2013. Nutritional and medical applications of *Spirulina* microalgae. Mini Rev. Med. Chem., 13: 1231-1237.
37. Mohamed, A.G., B.E. Abo-El-Khair and S.M. Shalaby, 2013. Quality of novel healthy processed cheese analogue enhanced with marine microalgae *Chlorella vulgaris* biomass. World Applied Sci. J., 23: 914-925.
38. Solowiej, B., 2007. Effect of pH on rheological properties and meltability of processed cheese analogs with whey products. Pol. J. Food Nutr. Sci., 57: 125-128.
39. Saad, S.A., L.D. El-Mahdi, R.A. Awad and Z.M.R. Hassan, 2016. Impact of different food protein sources in processed cheese sauces manufacture. Int. J. Dairy Sci., 11: 52-60.
40. Bachmann, H.P., 2001. Cheese analogues: A review. Int. Dairy J., 11: 505-515.
41. Awad, R.A., L.B. Abdel-Hamid, S.A. El-Shabrawy and R.K. Sıngh, 2002. Texture and microstructure of block type processed cheese with formulated emulsifying salt mixtures. LWT-Food Sci. Technol., 35: 54-61.