Yogurt enrichment with Spirulina (Arthrospiraplatensis): effect on physicochemical, textural properties and consumers acceptance

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Yogurt enrichment with *Spirulina* (*Arthrospiraplatensis*): effect on physicochemical, textural properties and consumers acceptance

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Abstract. Cyanobacterium*Spirulina* (*Arthrospiraplatensis*) is a filamentous multicellular, blue-green microalgae, known for its balanced biochemical composition (good quality proteins, balanced fatty acid profiles, vitamins, antioxidants and minerals). Moreover, since 1981, Food and Drug Administration has considered it as "generally recognized as safe" (GRAS) and recommends a consumption at a level up to 300 mg/kg body/day, when dried. Therefore this makes it interesting to incorporate into the formulation of novel functional products. The objective of the study was to develop a functional yogurt enriched with *Spirulina*. *Spirulina* powder (0.1-0.5 % of milk) was added to the standardized pasteurized milk, prior to lactic fermentation during manufacturing process. Physicochemical, textural and sensory properties were assessed. Preliminary formulations indicated that addition into yogurt of *Spirulina* powder in concentrations above to 0.3% of milk led to a weaker sensory acceptability. However, flavouring with vanilla/mint aromas has improved overall acceptability. Additional formulations showed that the incorporation of 0.12 and 0.24% resulted in a significant increase in proteins (up to +46%) and minerals contents (up to +23%) and in calorie value (up to +80%), but did not affect pH and syneresis. A higher curd strength was observed with 0.24%*Spirulina*-enriched product. Sensory quality was not affected by incorporating *Spirulina* up to 0.24% into yogurt. In conclusion the incorporation of *Spirulina* powder can enhance the nutritional quality of yogurt, without affecting its sensory properties.

Keywords. *Spirulina* – Functionalfoods – Nutritional value – Sensory quantitative descriptive analysis – Texture – Yogurt.

Enrichissement du yaourt avec la* Spiruline (Arthrospiraplatensis) : *effet sur les propriétés physicochimiques, texturales et l'acceptation des consommateurs

Résumé. *La cyanobactérieSpirulina (*Arthrospiraplatensis*) est une microalgue filamenteuse multicellulaire, bleu-vert, connue pour sa composition biochimique équilibrée (protéines de bonne qualité, profils d'acides gras équilibrés, vitamines, antioxydants et minéraux). En outre, depuis 1981, elle est classée comme «généralement reconnue comme sûre» (GRAS) et la Food and Drug Administration recommande une consommation journalière allant jusqu'à 300 mg/kg de masse corporelle, lorsqu'elle est séchée. Par conséquent, il est intéressant de l'intégrer à la formulation de nouveaux produits fonctionnels. L'objectif de l'étude était de développer un yogourt fonctionnel enrichi en spiruline. La poudre de spiruline (0.1-0.5 % de lait) a été ajoutée au lait pasteurisé standardisé avant fermentation lactique pendant le processus de fabrication. Les propriétés physicochimiques, texturales et sensorielles ont été évaluées. Les formulations préliminaires ont indiqué que l'addition dans le yaourt de poudre de Spiruline à des concentrations supérieures à 0.3 % de lait a conduit à une plus faible acceptation sensorielle. Cependant, l'aromatisation du yaourt enrichi par une combinaison vanille / menthe a amélioré l'acceptabilité globale. Des formulations supplémentaires ont montré que l'incorporation de 0.12 et 0.24 % a entraîné une augmentation significative des protéines (jusqu'à + 46%) et des contenus minéraux (jusqu'à + 23%) et en valeur calorique (jusqu'à + 80%), mais N'affecte pas le pH et la synérèse. Une résistance au caillé plus élevée a été observée dans le yaourt enrichi à 0.24 % de spiruline. La qualité sensorielle du yaourt n'a pas été affectée par l'incorporation de Spirulina jusqu'à 0.12%. En conclusion, l'incorporation de la poudre de Spiruline peut améliorer la qualité nutritionnelle du yaourt, sans affecter ses propriétés sensorielles.*

Mots-clés. *Spiruline – Aliments fonctionnels – Valeur nutritionnelle – Profil sensoriel – Texture – Yaourt.*

I – Introduction

The cyanobacterium*Spirulina(Arthrospiraplatensis*) planktonic blue–green algae, is gaining increasing attention because of its nutritional and medicinal properties. It is certified GRAS (Generally Recognized As Safe) and approved by the FDA since 1981. *Spirulina* is a source of proteins (up to 70%) and contains several minerals and vitamins such B12, B1 (thiamine), B2 (riboflavin), B3 (niacin) and tocopherol (vitamin E), as well as lipids (up to 7%) and essential fatty acids such as linoleic acid and γ-linolenic acid (Wells *et al*., 2017). The carbohydrate content is 15-20% of dry weight, composed of glucose and glycogen. Moreover, *Spirulina* is a valuable resource for natural antioxidants, such as phycocyanin pigments, carotenoids, and phenolic compounds (Wells *et al*., 2017). Interestingly, a noteworthy trend is the addition of *Spirulina* for the improvement of the nutritional properties of yogurt and fermented dairy products (Kavimandan, 2015). In fact, recent studies have shown that *Spirulina* can promote the growth of lactic acid bacteria not only in synthetic media but also in milk and yogurt (Kavimandan, 2015). The aim of this study was to investigate the effect of yogurt enrichment with *Spirulina* powder on physicochemical, textural and sensory quality of the yogurt.

II – Materials and methods

1. Materials

Spirulinaplatensis biomass was obtained from the Gatrana SA (SidiBouzid, Tunisia). The dried biomass contained 58% proteins, 1.5% lipids, 21% carbohydrates, and 9.41% ashes. Yogurt was manufactured by fermenting standardized pasteurized milk with the starter thermophilic culture (*Streptococcus salivarius subsp. thermophilus*and *Lactobacillus delbrueckiisubspbulgaricus*) according to standards ofSociétéLaitetDérivés (Tunisia).*Spirulina* powder (0.1-0.5 g per 100mL of milk, %) was added to the standardized milk, prior to fermentation step.

2. Analytical Analysis

Yogurtstitrable acidity, pH, total solids, ashes, fat (F) and proteins (P) contentsanalyses followed standard procedures and were performed in triplicate (AOAC, 2012).The carbohydrate (C) content was determined by subtracting the lipid, protein and ash contents from the solid content. The total caloric value was calculated by adding up the calories provided by the energy-containing nutrients, using the following calorie conversion factors: 4.27P+ 3.82C + 8.79F (Southgate, and Durnin, 1970). Syneresis (mL/125 g) was expressed as the exudate volume collected after 2h-refrigeration at 4°C. Apparent viscosity was measured by Rheomat FM180 (Rheometrics) equipped by coaxial cylinders (standard-size DIN) with a cylindrical rotor: height of the immersion roller (42mm),inner cylinder diameter (15mm).Thixotropic behaviour of the samples was evaluated by calculating the area of the hysteresis loop between the upward and downward shear stress/ shear rate curves. A sensory profile was performed by 10 trained panellists (ISO13299, 2016). Each attribute was quantified using the intensity scale (from 1 = not detected to 7 = extremely strong)

3. Statistical Analysis

Datas were analysed by One way ANOVA and Tukey test, using statistical software (GraphPad Prism V.4, 2003).A p value < 0.05 was considered significant for all analyses.

III – Results and discussion

1. Preliminary yogurt formulations

Prior to manufacturing of the final products for evaluation, preliminary formulation work was conducted in order to minimize the intense "*Spirulina*" algal flavour. Ten product prototypes with *Spirulina*doses ranging from 0 to 0.5% were formulated. Sensory preference evaluation indicated that incorporating a dose of *Spirulina* up to 0.3% and a combination of mint/vanilla aroma (0.07% in the milk prior fermentation) into the yogurt formulation minimized the inherent "*Spirulina*" flavour. As a result of the preliminary work, three lots of aromatised yogurts were manufactured containing 0 (control), 0.12% and 0.24% *Spirulina* powder. Addition of *Spirulina* did not affect hygienic quality of yogurt (data not shown).

2. Effect of Spirulina enrichment on flavoured yogurt quality

As shown in Table 1, addition of *Spirulina* at 0.24% led to a decrease of pH and an enhancement in titrable acidity ($p<0.05$). This increase in acidity was probably due to the fact that the S. platensis stimulated the growth of *L. bulgaricus* (Kavimandan, 2015).

Table 1. Physicochemical composition of flavoured yogurts enriched with increasing doses of *Spirulina* (n = 3)

Dose of *Spirulina*[1]	Titrable acidity (°D)	pH	Total solids (%)	Proteins (%)	Lipids (%)	Carbo-hydrates (%)	Ash (%)	Calorie value (Kcal/100g)
0%	79.0	4.61	21.0	3.63	2.56	14.19	0.65	54
0.12%	80.0	4.63	22.1	4.23	2.53	14.64	0.70	80
0.24%	95	4.57	22.9	5.30	2.63	14.17	0.80	99
$p_{\alpha=0.05}$[2]	0.042	0.31	<0.01	<0.001	0.18	ND[3]	<0.001	ND[3]

[1] %: g of *Spirulina* into 100 mL milk prior lactic fermentation.
[2] Tukey's Significant Difference.
[3] Not determined.

Total solid, protein and ash contents of yogurts with *Spirulina* were significantly higher than those of the control ones, because of the *Spirulina* biochemical characteristics (see Materials). There was no significant difference in carbohydrate and fat contents. Addition of *Spirulina* led to an increase in the yogurt calorie value. Similar results were observed by Shin *et al*. (2008) and Malik *et al*. (2013) on yogurts containing up to 0.5% of *Spirulina*.

As indicated in Table 2, addition of *Spirulina* has not significantly affected syneresis.

Table 2. Syneresis, viscosity and pressure drop properties of flavoured yogurts enriched with increasing doses of *Spirulina* (n = 3)

Dose of *Spirulina*	Syneresis (mL/125g)	Viscosity (Pa.s)	deltaP (Pa)
0	0.86 ± 0.11	3.15 ± 0.19	$5{,}105.10^5$
0.12	0.88 ± 0.10	3.37 ± 0.11	$4{,}707.10^5$
0.24	0.90 ± 0.10	3.59 ± 0.09	$3{,}723.10^5$
$p_{\alpha=0.05}$	0.401	<0.05	<0.01

Interestingly, the apparent viscosity of yogurts was increased with the addition of *Spirulina* in yogurt formulation.Similar results were found by Shin *et al*. (2008) and Malik *et al*. (2013) who found a higher viscosity in *Spirulina* enriched yogurts, when compared to the controls. Decrease in thixotropic value in the yogurt enriched with *Spirulina* indicated a better stability of the enriched product.This can be explained by the higher protein contents in *Spirulina* enriched yogurts, as shown in Table 1.Protein composition has been shown to influence the structure and texture characteristics of yogurts (Lee and Lucey, 2010).

Quantitative descriptive analysis of yogurts enriched with increasing doses of *Spirulina* revealed no significant effect of *Spirulina* addition onperceived milky odour, herbal odour, texture, sweet flavour, acid flavour, bitter flavour, algal taste, and herbal taste intensities (Fig. 1). However incorporating 0.24% of *Spirulina* powder into yogurt has induced a significant change in algal odour and after taste intensities. Interestingly, as confirmed by a preference test on 106 consumers(data not shown), this difference has not impaired the consumers' acceptance.

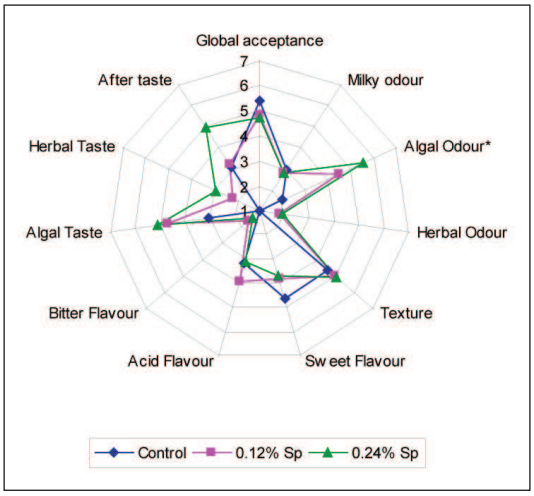

Fig. 1. Quantitative descriptive sensory evaluation of flavoured yoghurtsenriched with increasing doses of *Spirulina* (n = 10 trained panellists).

IV – Conclusion

Overall, our results showed that addition of *Spirulina* up to 0.12% into yogurt has improved the nutritional value of yogurt, without altering consumers' acceptance. This research identified the qualities that need further development and demonstrated the importance of early-stage consumer acceptance research for directing new product development.

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