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Aliments et nutriments

Gluten-free pasta enriched with whey for celiac patients

Pâtes alimentaires sans gluten enrichies par du lactosérum pour malades cœliaques

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Abstract ***Introduction.*** Manufacturers and celiac patients have long complained about gluten-free (GF) pasta for its poor cooking properties, and reduced nutritional value. Therefore, it was imperative to develop GF foods that are acceptable to the consumer. ***Objective.*** The effect of different levels of sweet whey (SW), and acid whey (AW) was evaluated on cooking and sensory quality of rice-corn GF pasta. ***Material and methods.*** The physicochemical characteristics (pH, acidity, dry extract, proteins, fats, ash, and lactose contents) of whey samples were determined. For pasta-making, whey was added at different levels (25, 50, 75 and 100%) in replacement of water. GF pasta prepared without whey addition, and commercial durum wheat pasta (CWP) were considered as controls. Cooking quality (optimum cooking time (OCT), water absorption capacity (WAC), and cooking loss (CL)), as well as, sensorial quality were assessed. ***Results.*** GF pasta prepared with high levels of whey had significantly higher OCT, and lower WAC than control GF pasta. Control wheat pasta exhibited highest values (p<0.05) of these parameters. The incorporation of 25 and 50% of AW resulted in a significant decrease in CL. Moreover, sensory quality was improved by the addition of 50% of AW. ***Conclusion***. An improvement of cooking and sensory quality of GF pasta is achieved by the addition of 25 and 50% acid whey.

Key words: *Rice, Corn, Acid whey, Sweet whey, Gluten-free pasta*

Résumé ***Introduction.*** Les fabricants et les malades cœliaques se sont plaints depuis longtemps des pâtes sans gluten (SG) pour leurs faibles propriétés de cuisson et leur valeur nutritionnelle réduite. Il était donc impératif de développer des aliments sans gluten acceptables pour le consommateur. ***Objectif.*** L'effet de différents niveaux de lactosérum doux et acide a été évalué sur la qualité culinaire et sensorielle des pâtes SG à base de riz et de maïs. ***Matériel et méthodes.*** Les caractéristiques physico-chimiques (pH, acidité, extrait sec, protéines, graisses, cendres et lactose) des échantillons de lactosérum ont été déterminées. Pour la fabrication des pâtes, le lactosérum a été ajouté à différents niveaux (25, 50, 75 et 100%) en remplacement de l'eau. Les pâtes sans gluten préparées sans ajout de lactosérum et les pâtes commerciales de blé dur ont été considérées comme des témoins. La qualité culinaire (temps optimal de cuisson (TOC), capacité d'absorption de l'eau et pertes à la cuisson) ainsi que la qualité sensorielle ont été évaluées. ***Résultats***. Les pâtes sans gluten préparées avec des niveaux élevés de lactosérum ont présenté un TOC significativement plus élevé et une capacité d'absorption d'eau plus faible que les pâtes sans gluten témoins. Les pâtes de blé témoin ont présenté les valeurs les plus élevées (p<0,05) de ces paramètres. L'incorporation de 25 et 50% de lactosérum acide a entraîné une diminution significative des pertes à la cuisson. De plus, la qualité sensorielle a été améliorée par l'ajout de 50% de lactosérum acide. ***Conclusion.*** Une amélioration de la qualité culinaire et sensorielle des pâtes sans gluten est obtenue par l'ajout de 25 et 50% de lactosérum acide.

Mots clés : *Riz, Maïs, Lactosérum acide, Lactosérum doux, Pâtes sans gluten*

Introduction

The increased prevalence of celiac disease led to an increased demand for GF products including pasta [1-2]. A high degree of firmness and elasticity, termed “al dente” is considered a sign of good quality pasta. This consistency is difficult to obtain when using gluten-free raw materials. Cooked GF pasta is often too soft, and the mouth feel is not comparable to wheat counterparts [3]. Therefore, the replacement of gluten presents a major technological challenge leading to the search for alternatives to gluten in the manufacture of GF pasta products [4-5].
Various wheat flours substitutes have been used for GF pasta production, including pseudo-cereals, legume flours, and vegetables or fruits powders. However, the most popular raw materials are rice and corn [6]. Furthermore, most of the extruded GF products found in the market include white or polished rice and corn, as main ingredients, due to their abundance, low cost and high expansion capacity [7-8]. However, they are limited in terms of their nutritional properties, and they have relatively poor technological properties for interaction and development of a cohesive network [9]. One of the approaches used for GF pasta-making is based on the choice of appropriate ingredients and/or additives suitable for inducing a cohesive structure that overcomes the absence of gluten [10].
Whey is the liquid portion produced during cheese-making or during coagulation of the milk casein process as a byproduct [11]. It may be sweet or acid depending upon the type of casein or cheese coagulated; it represents about 85-90% of milk volume, and retains approximately 55% of milk nutrients [12]. The main proteins present in milk are whey protein and casein. It is rich in calcium, phosphorus, essential amino acids, and water-soluble vitamins, which makes whey a highly nutritious product [13]. Whey can be incorporated advantageously into various food formulations, including cookies, breads, cake, crackers, pasta, confectionary products, ice creams, soups and gravies, frozen desserts, beverages, infant food formulations, and special dietetic food [14].
The aim of the present study was to evaluate the effect of different levels of sweet, and acid whey on cooking, and sensory quality of rice-corn GF pasta.

Material and methods

Raw materials

Rice and corn flours were provided by BioAglut SARL Company (Constantine, Algeria). The chemical composition per 100 g dry raw materials was as follow: rice flour-protein 7g, fat 1.8g, carbohydrates 78g, fiber 1g; corn flour–protein 7.9g, fat 1.8g, carbohydrates 74g, fiber 3.2g.
SW used in the experiments was obtained during the production of camembert cheese, and supplied by

Numidia dairy company (Constantine, Algeria). AW was prepared according to the method described by Leksir *et al*., [15]. It was obtained from the manufacture of a traditional cheese called "*Klila*", which was prepared by moderate heating of acidulated cow's milk (*Lben*) until whey was separated. Samples of the both types of whey were kept in sealed containers, and frozen at-24°C until their use.

Physicochemical characteristics determination of acid and sweet whey samples

Physicochemical characteristics were determined, for pH using pH-meter (HANNA instruments pH 210, Romania), acidity by titration of lactic acid with sodium hydroxide at 0.1 mol/L as described by AFNOR [16], ash by incinerating dry matter at 550°C for 8 h in a muffle furnace [16], dry extract according to AFNOR [17] by drying whey in an oven at 105°C for 24h until complete water evaporation. Lipid content was determined using Gerber method which is based on centrifugation in a butyrometer after dissolving proteins with sulfuric acid. Lipid separation was facilitated by addition of amyl alcohol small amount [18]. Soluble proteins were determined using Bradford technique, a colorimetric method which involves the binding of Coomassie Brilliant Blue G-250 to protein, resulting in a change in absorbance at 595 nm [19]. Lactose content was assessed by standard Bertrand method [20], based on the sample heating in the presence of Fehling solution.

Pasta production

A formula composed of a mixture of 2/3 rice flour and 1/3 corn flour (w/w) was used in GF pasta production. Two types of pasta were prepared: GF pasta with whey addition (25%, 50%, 75% and 100% of SW or AW), and GF pasta without whey addition (CGF) in which only water was added. The process of pasta-making was as follow: first, the formula was prepared by blending rice and corn flours manually, then water and/or whey were added in order to produce a mixture with final moisture of 40%. The mixture was mixed for 5 min and formed into a pasta-making machine fitted with a spaghetti die (SIMAC PASTAMATIC junior plus 230W, Italy). Finally, all pasta samples were pre-dried for 12 min at 30°C and then dried for 4 h at 45°C in an air oven. After drying, pasta samples were stored in sealed plastic bags at room temperature until analysis. Commercial durum wheat spaghetti was bought from a local market and used as control pasta.

Cooking quality

Cooking quality was determined in triplicate according to AACC methods [21].

Optimum cooking time (OCT)

Ten grams of pasta were cooked in 200 mL of boiling distilled water (without adding salt). At regular time intervals, i.e. every 30 seconds, a strand of pasta was taken out, and immediately squeezed between two glass plates. The time at which the core of pasta completely disappeared was considered as the optimum cooking time.

Water absorption capacity (WAC)

Ten grams of pasta were cooked in 200 mL of boiling distilled water according to their OCT, rinsed with 100 mL of cold distilled water, and left to drain for 3 min. The WAC of pasta was calculated as follow:

WAC % = (Wc - Wr/ Wr) × 100

Wc: weight of cooked pasta (g) ; Wr: weight of uncooked pasta (g).

Cooking loss (CL)

CL, defined as amount of solid substance lost in cooking water, was measured by drying pasta cooking and rinsing waters collected in a glass-beaker in an air oven at 105°C until a constant weight was reached. The residue was weighed, and reported as a percentage of the starting material.

Sensory analysis

Cooked spaghetti samples (CWP, CGF pasta and GF pasta enriched with 50% of AW) were submitted to a panel of 20 trained persons in order to evaluate different sensory attributes like: appearance, color, firmness, stickiness, taste, and overall acceptability using a nine-point hedonic scales, where 9 = extremely like, and 1 = extremely dislike [22].

Statistical analysis

Statistical analysis of data was performed using statistical software XLSTAT (2009). Results are expressed as mean ± standard deviation. Comparison between several means was performed by analysis of variance (ANOVA) followed by Fisher LSD at $p< 0.05$.

Results

Physicochemical characteristics of whey samples

Physicochemical characteristics of sweet whey and acid whey used in GF pasta-making are presented in **Table 1**. Acid whey was significantly more acidic (pH = 4.28, and acidity = 58.62 °D), richer in ash (0.52%), poorer in soluble proteins (4.6 g/L) than sweet whey. No significant differences was observed for dry extract, fat and lactose contents of whey samples.

Table 1. Physicochemical characteristics of sweet and acid whey samples

Characteristics	Sweet whey	Acid whey
pH	6.21±0.05[b]	4.28±0.005[a]
Acidity °D	14±1[a]	58.62±0.57[b]
Dry extract (%)	5.63±0.04[a]	5.5±0.18[a]
Fat (%)	0.43±0.05[a]	0.23±0,05[a]
Proteins (g/L)	7.1±0.98[b]	4.6±0.28[a]
Ash (%)	0.52±0,65[a]	0.73±0,86[b]
Lactose (g/L)	46.5±0.25[a]	45.25±0.35[a]

[a-b]Means with different superscript letters within a line are significantly different (p < 0.05).

Cooking quality

Results of optimum cooking time, water absorption capacity and cooking loss of pasta samples are shown in **Table 2**.

Table 2. Cooking quality of pasta samples

Pasta	OCT	WAC	CL
CWP	13.38±0.36[d]	179.45±0.23[d]	4.31±0.28[a]
CGF	4.2±0.16[a]	129.08±0.52[c]	15.75±0.03[c]
P25S	4.39±0.09[a]	135.47±0.66[c]	13.02±0.01[bc]
P50S	5.23±0.76[ab]	118.23±0.57[b]	14.27±0.27[bc]
P75S	6.29±0.21[bc]	118.41±0.91[b]	13.89±0.46[bc]
P100S	5.22±0.32[ab]	107.01±0.51[a]	12.57±0.06[bc]
P25A	6.38±0.55[bc]	117.82±0.42[b]	11.70±0.45[b]
P50A	5.25±0.09[ab]	108.67±0.49[a]	11.57±0.99[b]
P75A	6.33±0.19[bc]	113.04±0.33[ab]	13.35±0.64[bc]
P100A	7.26±0.30[c]	113.76±0.52[ab]	15.27±0.16[c]

[a-d]Means with different superscript letters within a row are significantly different (p < 0.05). CWP: commercial wheat pasta; CGF: control gluten-free pasta; P25S, P50S, P75S and P100S: pasta with 25%, 50%, 75% and 100% of sweet whey. P25A, P50A, P75A and P100A: pasta with 25%, 50%, 75% and 100% of acid whey.

Optimum cooking time

OCT of GF pasta samples ranged from 4.2 to 7.26 min. Durum wheat pasta (CP) had significantly longer OCT (13.38 min) than gluten-free pasta samples. Moreover, for GF pasta samples, OCT increased as the amount of SW and AW enhanced (r=0.75 and r=0.81, respectively). It passed from 4.2 min for GF pasta without whey addition to 5.22 min for pasta with 100% SW, and 7.26 min for pasta with 100% AW.

Water absorption capacity

WAC of GF pasta samples decreased with the elevation of SW incorporation (r=-0.88) or AW (r=-0.72). WAC of GF pasta samples varied between 107.01% and 135.47%. CP absorbed significantly more water (179.45%) than GF spaghetti samples.

Cooking loss

CL of GF pasta samples varied from 11.57 to 15.75%. CP had the lowest (*p*<0.05) loss of material in cooking water (4.31%). Incorporating SW in the formulation did not promote significant changes in the amount of material lost during cooking. In contrast, addition of 25% or 50% of AW caused a significant decrease in CL (11.70 and 11.57%, respectively) compared to GFP. However, despite this significant decrease in CL, it couldn't be compared to those of CP.

Sensorial quality

Results of sensory analysis are shown in **Fig. 1**.

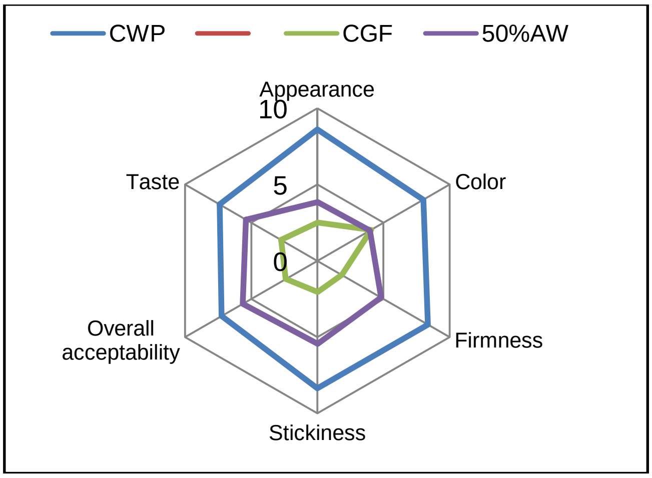

Fig. 1. Sensory attributes of control wheat pasta, control gluten-free pasta and gluten free pasta with 50% AW

CWP: control wheat pasta; ***CGF: control gluten-free pasta; GF; AW:*** *acid whey.*

CP had significantly higher scores for all sensory attributes (between 7.25 and 8.6) compared to GFP (between 1.85 and 4.05), and pasta with 50% AW (between 3.95 and 5.65). Furthermore, GF pasta enriched with 50% AW had higher scores (*p*<0.05) for all sensory attributes (appearance, firmness, stickiness, taste and overall acceptability) when compared to GFP, excepted for color.

Discussion

In the present study, the effect of different levels of SW and AW on the quality of gluten-free pasta based on rice-corn recipe was evaluated. Whey composition vary depending on several factors including kind of whey (acid or sweet), source of milk (cow, sheep, bovine milk, *etc*.), feed of animal that produce milk, cheese processing method, period of year, and stage of lactation [23]. Both pH and acidity results confirmed the kind of each whey which were within the reported ranges of the literature [24-25] : pH between 5.8 and 6.6, and acidity between 10 and 20 °D for SW; and pH between 4.0 and 5.0, and acidity between 40 and 60 °D for AW. Results of whey proteins and lactose were also in the typical ranges as reported by Božanić *et al*., [26], and Onwulata and Huth [27] with SW containing 46-52% lactose and 6-10% proteins, while AW containing 44-46% lactose and 6-8 % proteins. However, detected values of ash and dry extract were lower than those reported in previous studies [27-29] respectively; which were 2.5-4.7% ash and 7% dry extract for SW; 4.3-7.5% ash and 6.5% dry extract for AW. Fat contents were close to those reported by Božanić *et al*., [26] and Chandan *et al*., [29], which were 0.5 and 0.3 for SW and AW, respectively.

Durum wheat pasta had significantly longer cooking time than GF pasta. This difference could be explained by the absence of gluten in GF pasta, which would make its structure more fragile, thus facilitating water penetration during cooking [30-31]. As reported by Lorenzo *et al*., [32], the cooking time depends on the rate of water diffusion into the pasta, so it is strongly related to the pasta formulation and processing conditions, which both affect the final structure of the matrix.

The longer time of pasta enriched with whey could be explained by a slower gelatinization of starch caused by the presence of whey proteins. In fact, the encapsulation of starch by proteins would limit their water absorption, thus increasing the time needed for water to reach the center of the dough during cooking [33-34].

The weight of cooked pasta indicates the water uptake, and corresponds to a macroscopic event involving a complex molecular modification of starch and proteins, mainly hydration [35-36]. Water absorption is considerably affected by pasta formulation [37]. It should also be noted that water absorption occurs through the protein network, as well as, through the starch [33-34].

The low level of WAC observed for GF pasta with whey addition could be explained by the reduction in the water amount required for starch swelling, a consequence of the possible competition of the different biopolymers for available water after whey addition, as pointed out by Kumar *et al*., [38] and Ungureanu-Luga *et al.*, [39].

Wheat pasta had higher WAC compared to GF pasta. This could be related to the longer OCT of wheat pasta, since more water can diffuse and interacts with both starch and protein matrices [36-40]. During cooking, dried gluten acts as a sponge for water, opens its structure and embeds the starch granules inside this network [36].

CL is widely used as an indicator of the overall cooking performance, as it is considered as a resistance index to disintegration during cooking [41].

The higher CL of GF pasta compared to durum wheat pasta could be related to the absence of gluten in GF pasta which leads to less efficiently entrapped starch polymers in the matrix, thus, giving products with higher CL [10,42].

The use of 25% or 50% of AW reduced the GF pasta CL, and seemed to be efficient as for limiting the leaching of solid into the cooking water probably due to the pasta constituents incorporation into whey protein gels, as a result of protein coagulation during cooking, resulting in better starch retention in the matrix, and thus, lower solids loss [10]. Similar data were reported by Marti *et al*., [10] for pasta made from parboiled rice flour, and supplemented with whey protein and by Ungureanu-Iuga *et al*., [39] for corn pasta with the addition of whey powder.

A small amount of lost matter is a sign of high-quality cooked pasta [32,43]. According to Hoseney [44], a good quality pasta should present cooking losses below 12%. Therefore, only pasta with 25% and 50% of AW could be considered as acceptable. However, despite the positive effect of AW addition on CL, the obtained results exceeded the limit considered for good quality of industrial spaghetti (7-8%) [45].

Conclusion

The obtained results show that the use of both SW and AW increases the optimum cooking time and lowers the water absorption capacity of GF pasta. In contrast, cooking loss is not affected by the whey incorporation, excepted for GF pasta with 25 and 50% of AW that record significantly lower values than the other GF pasta. Furthermore, the addition of 50% of AW has a positive effect on the sensorial attributes as it improves firmness, stickiness, taste and overall acceptability of GF spaghetti, as well as, nutritional value. Further research would be interesting to looking for other texturing ingredients for producing GF pasta with improved quality in terms of cooking, textural and sensorial properties.

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Conflict of interests

The authors declare no conflict of interests.

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