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Wheat Substitutes for Gluten-Free Pasta: An Integrative Review

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Abstract

Pasta are present in the basic basket of the Brazilian population and constitute one of the main substitutes for rice. The ingredient traditionally used in the preparation of these pastas is wheat flour, in which gluten is present. Gluten is proven to be related to some diseases that have been increasingly common in our population. The aim of this work was conduct an integrative review on the main wheat substitutes in the preparation of gluten-free pasta. For this, the following question arose: what are the current substitutes for wheat in the preparation of gluten-free pasta? The survey was conducted from January to June 2019, in the main electronic databases and online platforms. 84 articles were found, and 14 articles were included because they were eligible. Thirteen different raw materials were found, used in the preparation of noodles, rice being the most prevalent in substitution to wheat. The range of ingredients that can be used for wheat substitution is evident, but it is expected that further studies will be carried out in order to be able to produce pasta with characteristics closer to those offered by gluten and that are sensorial accepted by the population.

Keywords: Gluten free; Celiac disease; Pasta; Nutrition.

1. Introduction

Paste or pasta, in accordance with Brazilian law, is characterized by being products obtained from wheat flour and / or durum wheat or other cereals, legumes, roots and / or tubers, resulting from the process of paste and mechanical kneading, without fermentation, [1] including macaroni, popular designation for pasta.

This product arrived in Brazil through Italian immigrants around 1870, and it is currently considered by the population a popular rice substitute food, being part of the basic basket of Brazil [2].

Currently the country is considered the third largest market consuming pasta. These are prepared primarily with water and wheat flour, with over 60 variations of shapes and compositions of these products. In Brazil, the most common types are semolina, hard grain, wholemeal, added eggs and colorful noodles. Among consumer preferences, spaghetti stands out as the main (80%), followed by fusilli (7.3%) and lasagna (2.7%) [3].

Wheat has gluten in its composition, which is a protein compound formed by the mechanical junction of gliadin and glutenin via hydrogen bonds, van der Waals bonds and disulfide bonds, which produce a viscoelastic mass. This is the main protein portion present in wheat flour used in the preparation of pasta [4]. Gluten is also present in other cereals such as rye and barley, and can be found in oats by cross contamination.

Gluten is related to some diseases such as celiac disease, non-celiac gluten intolerance and wheat allergy, which have been increasingly reported and frequent in the population. Studies estimate that celiac disease affects around 2 million people in Brazil, but most of them are still undiagnosed [5].

Individuals with celiac disease manifest intestinal discomfort, nutrient malabsorption and, in more severe cases, may reach malnutrition. Celiac disease is an autoimmune response to gluten when it is exposed to the small intestine, whose symptoms are related to morphology and digestion [6]. Intolerance or sensitivity to non-celiac gluten (CNMS) is characterized by difficulties in gluten digestion. But serological tests are negative and intestinal biopsy is normal [7]. Wheat allergy manifests minutes or hours after ingestion of gluten, the allergen, and usually presents with skin, gastrointestinal and respiratory reactions.

Celiac disease is considered a public health problem due to its high prevalence. According to the Ministry of Health [8], the lack of information about the disease and difficulty in accessing the diagnostic means underestimate studies on its prevalence. This is an unhealed disease and since the 1950s the gluten free diet has been recognized as the most effective treatment.

In this sense, pasta products that do not use wheat as their main ingredient are being developed, meeting these needs and also the demands of people who choose to remove gluten from the diet for the sake of “lifestyle”. Thus,

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the aim of this paper is to conduct an integrative review to identify the main wheat substitutes in the preparation of gluten-free pasta.

2. Methodology

This is an integrative review, in which a survey was conducted on the main wheat substitutes in the preparation of pasta.

The construction of this integrative review is based on the study by Ganong [9], constructed by six steps: theme selection, establishment of inclusion criteria, definition of information to be extracted from studies, evaluation of studies, interpretation of results and presentation of the review.

The study was guided by the following research question: What are the current wheat substitutes in the preparation of gluten-free pasta? The articles were collected from January to June 2019, in the electronic databases of Latin American and Caribbean Health Sciences Literature (Lilacs), Medical Literature Analysis and Retrieval System Online (Medline / via PubMed) and platforms such as Scientific Electronic Library Online (Scielo), as well as journals, dissertations, theses, government reports, and references from included studies. The terms used and identified in the controlled vocabulary of the Health Sciences Descriptors (DeCS) were celiac disease and the Medical Subject Headings (MeSH) were “gluten free” and “paste” with the Boolean operator “AND” in the association.

As inclusion criteria were considered articles with abstract and full text related to the proposed theme, published in English and Portuguese. We also searched for articles in the Spanish language, but were not found. We considered articles published from 2009. Repeated articles were excluded from the database, articles not fully available, works that, despite having been selected by title, did not maintain relationship with the objective of this study after reading the abstract.

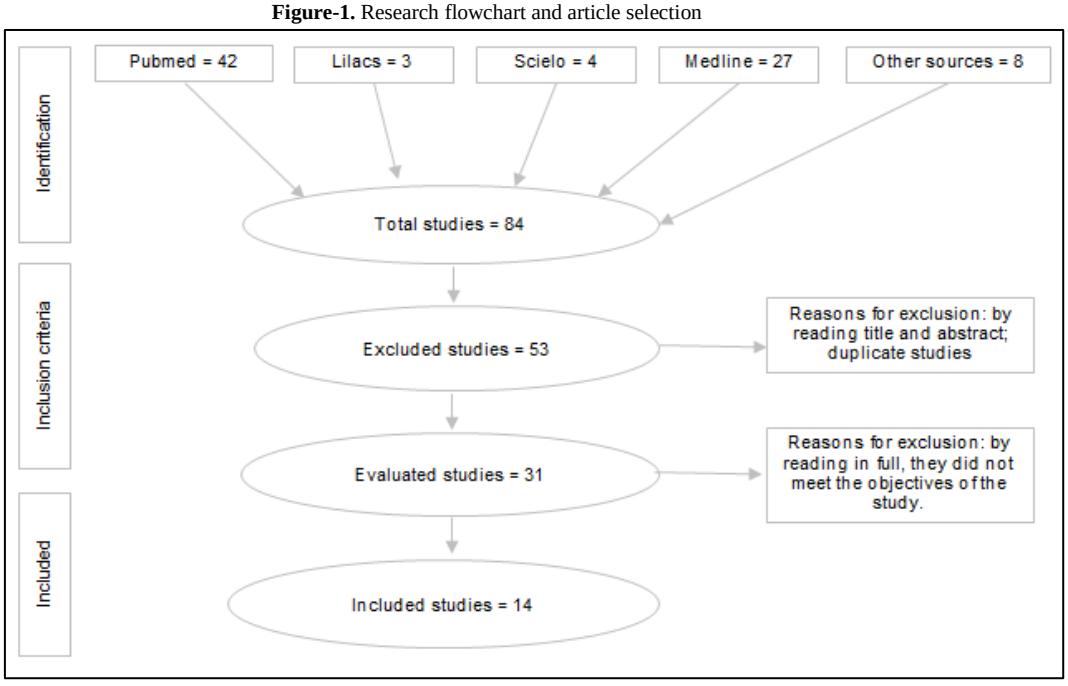
The selection of studies was performed primarily by reading titles, reading abstract and last reading the full article. Mendeley was used to manage references.

A descriptive table presented the results, considering the following aspects: article reference, objective, main raw material used, yield, acceptability and nutritional characteristics, in order to enable the reader to evaluate the studies selected in the integrative review approach.

3. Results and Discussion

Initially, identified 84 articles. After the initial screening, eliminated 70 articles because they were duplicate and did not include the theme, resulting in an integrative review with 14 articles that presented eligibility, according to the flowchart presented in Figure 1.

Figure-1. Research flowchart and article selection



Of the 14 studies selected, 7 were international (Poland, Mexico, Thailand, Argentina and Colombia) and 7 national, and Brazil was the country that published the most on the subject, according to the established inclusion criteria. The time range of the selected publications was from 2010 to 2019 and the journal that published the most was Food Science and Technology. The predominant language was English, which was used in nine of the fourteen studies, and the predominant type of study on the subject was experimental design.

This study allowed the identification of several raw materials that are used for the substitution of wheat in the preparation of pasta, which has favored the food industry to meet the demands of segments of the population for gluten-free products, either for physiological reasons "lifestyle" (Table 1).

Table-1. Alternative raw materials to wheat in the preparation of gluten free pasta

Raw material	Absolute value (n)	Relative value (%)
Rice	9	64.3
Corn	5	35.7
Sorghum	3	21.4
Soy	2	14.3
Green banana	2	14.3
Chickpeas	2	14.3
Amaranth	2	14.3
Pea	2	14.3
Cassava	1	7.1
Quinoa	1	7.1
Lentil	1	7.1
Linseed	1	7.1
Potato starch	1	7.1

The high demand for gluten-free products by celiac patients and people opting for a diet free of this component encourages further studies involving the use of various raw materials, either alone or in combination to replace wheat flour in traditional products, like the noodles.

In this review, 9 of the 14 articles [10-18] selected used rice as one of the ingredients and the study by Giménez, *et al.* [19] used this cereal as the sole ingredient.

Rice is therefore the traditional raw material most commonly used for wheat substitution. Rice flour is obtained from broken grain residues (quirera), which is the most commonly found gluten free pasta in the markets.

The second most cited ingredient in the selected articles was cornmeal [12, 14, 18, 20, 21]. Some variations were used by the authors, such as Andean corn [14] grown in Argentina which adds to the masses a supply of dietary fibers, minerals, B vitamins and phytochemicals, such as polyphenols, but in these studies the nutritional aspects were not analyzed.

Thus, Table 2 presents the selected studies, with their data in descriptive form, considering the established criteria, such as authors and publication data, the respective raw materials used, objectives, cooking time, yield, nutritional aspects and acceptability of elaborated products.

Table-2. Summary of studies on gluten-free pasta from 2009 to 2019

Author/ Year	Raw material	Objetives	Cook time (minutes)	Yield (%)	Acceptability
Ramírez, *et al.* [20]	Cassava Flour (26g) +, Amaranth Flour (12g) / 100g	Determine optimal conditions for using gluten-free pasta mix	-	-	5 point hedonic scale: 2 (fish and earth flavor)
Camelo-Méndez, *et al.* [12]	Cornmeal (blue and white) (50%), green banana flour (25%), chickpea flour (25%)	Analyze the phenolic profile, color and antioxidant capacity of gluten free pasta based on unconventional flour	-	-	-
Ferreira, *et al.* [14]	Sorghum (40%) + rice (20%) + potato starch cornmeal (40%).	Get gluten free pasta based on sorghum flour + rice + corn and potato starch	11	391.46	9 point hedonic scale: Quality: 7.33 Taste: 6.5
Giménez, *et al.* [19]	Cornmeal; Cornmeal; Rice flour	Compare the sensory profile between spaghetti of different compositions	12 7 6	-	a) and b) no acceptability; c) sticky, with strange odor and taste, but accepted by celiac
Zandonadi, *et al.* [18]	Green banana flour	Obtain and analyze gluten-free green banana flour dough	8	452.38	Good acceptability: 84.5% for celiac and 61.2% for non-celiac
Tomicki, *et al.* [21]	Rice flour (60g) + Corn flour (40g)	Evaluate rice flour + corn	2	-	9 point hedonic scale: 7.66

		mix on sensory and physicochemical quality of gluten-free pasta			
[17]	(1) Sorghum flour (2) 50% sorghum flour and 50% cornmeal (3) Cornmeal	Obtain dried pasta with sorghum and corn flour, and evaluate chemical, cooking and sensory characteristics by celiac and non-celiac	(1) 5.5 (2) 5.5 (3) 7.5	(1) 122.7 (2) 143.1 (3) 108.1	10 point hedonic scale: (1) 4.61 (2) 5.48 (3) 6.82
Moura [16]	Rice Flour 47g Flaxseed 10g Pregelatinized Rice Flour 43g / 100g	To evaluate the cooking properties and texture of noodles based on mixed flour mix	8	-	-
Kirinus, *et al.* [2]	(1) Soy (2) Quinoa	Develop two different types of gluten-free homemade pasta and assess acceptance.	(1) 13 (2) 15	-	7 point hedonic scale: (1) 4.1 (2) 2.6
Martins [15]	Red sorghum flour (75%) and brown rice flour (25%)	Produce more nutritious gluten-free pasta and higher technological and sensory quality	9.3	173	9 point hedonic scale: 6.83
Detchewa, *et al.* [13]	95% rice flour (85.5% high amylose rice + 9.5% waxy rice) + 5% soy protein isolate	To investigate the effects of soy protein isolate on the morphological, thermal, cooking, texture and sensory properties of gluten-free rice spaghetti	13.7	248.1	9 point hedonic scale: 6.16
Bouasla, *et al.* [10]	Rice Flour + (1) 30g yellow pea (2) 30g chickpeas (3) 30g of lentil	To evaluate the chemical composition, physical and sensory properties of gluten-free rice masses enriched with different levels of legumes	(1)8 (2)9 (3)8	(1) 464 (2) 474 (3) 474	9 point hedonic scale: (1) 2.93 (2) 3.33 (3) 3.87
Cabrera-Chávez, *et al.* [11]	75g of rice flour and 25g of amaranth flour / 100g	Get high quality rice pasta supplemented with amaranth	-	-	-
Bouasla, *et al.* [22]	Yellow pea flour and rice flour	To evaluate the influence of moisture and mass formation velocity on the	9	-	7.60

		phenolic compounds of the obtained products			

The development of pasta without the use of wheat and other types of raw materials also requires strategies that favor gluten replacement. Such strategies for obtaining pasta with gluten-like textures include the use of texture enhancers such as carboxymethylcellulose (CMC) and xanthan gum, as reported by Ramírez, *et al.* [20].

Ramírez, *et al.* [20], used a mixture of amaranth flour (which has higher protein content (12 and 16%) than wheat (10%) + cassava flour. They observed that the minerals contained in the amaranth flour acted with the CMC forming a network. However, they pointed out that the pasta obtained was not indicated for celiac because it had a real gluten content of 26.1mg.kg^{-1}, higher than the minimum recommended amount in these cases, which should be 20mg.kg^{-1}. The presence of gluten observed may have been due to cross contamination due to the fact that amaranth processing is normally done at the same location and machinery as wheat.

Pseudo-cereals are seeds characterized by an excellent nutrient profile and are important sources of energy due to their starch content [23]. Amaranth (Amaranthus spp.) Is a pseudo-cereal whose protein content is of high biological quality, due to its high content of essential amino acids, in particular lysine, and can thus be a complement to rice, maize and wheat proteins [24]. Cabrera-Chávez, *et al.* [11], in their study compared amaranth with rice flour and found that it also increased protein as well as fat content.

Another pseudo-cereal used as a substitute for wheat was quinoa (*Chenopodium quinoa*) which, like amaranth as well, contains essential amino acids of high biological value. However, the authors reported that the quinoa noodles obtained had a strong odor, being negatively evaluated in the sensory test by the judges, who indicated an average grade of 2.6 on a 7-point scale, configuring non-acceptance of the product [2].

Sorghum (*Sorghum bicolor* L.) is a cereal whose grains are sources of protein, starch and antioxidant compounds [25]. It was the third most observed raw material in this review [14, 15, 17]. In the study by Paiva, *et al.* [17] sorghum and maize flour were analyzed separately in the preparation of the dough compared to a mixture of sorghum flour + cornmeal. The mass made only with sorghum, flour obtained the highest protein value compared to corn and the mixture of both, but it obtained the lowest score on the sensory acceptability scale. The authors point out that this low score was due to the characteristic bitter taste of the phenolic compounds present in sorghum, which help to prevent the formation of free radicals in our body [25].

Regarding sensory evaluation, the products were evaluated using a 9-point hedonic scale [11, 13-15, 21], 7-point hedonic scale [2], 10-point hedonic scale [17], percentage [18], check-all-that-apply (CATA) questions [19] or 0 to 5 point scale [20] and one of the studies did not report the point scale used [22]. Many of the studies [2, 13, 17, 19, 20] have obtained low acceptance indicating that more technologies and research need to be studied and employed in gluten replacement.

Ramírez, *et al.* [20], reported having low acceptance by using a tuber as the main ingredient (cassava) which left its earthy flavored mass described by the evaluators. Giménez, *et al.* [19], performed the evaluation with 85 individuals, among which 55 were non-celiac and habitual consumers of wheat-based pasta, which according to them may have interfered with the acceptability of their sample.

Still regarding the sensorial tests, some authors report that their final products also did not obtain good score due to the absence of tomato sauce composing the samples, classic form and usually consumed, as well as by the temperature below which the pasta is culturally served. This demonstrates an error in conducting the sensory test, as it is important to take proper care with the presentation and temperature of the sample served to the judges. However, the absence of the sauce cannot justify the low acceptance, as its presence could mask the taste of the sample.

Another important point is that these analyzes are performed by celiac patients, who are the target audience, or by individuals who choose to remove gluten from their diet, so that the preference for gluten texture and taste does not interfere with the acceptability of gluten free pasta.

Regarding income, the study by Zandonadi, *et al.* [18], with the green banana noodles obtained the highest yield - an aspect attributed to the high power of water absorption by the green banana flour - followed by Ferreira, *et al.* [14], who used the sorghum mixture (40%) + rice flour (20%) + cornmeal and potato starch (40%), the latter being responsible for giving firmness to the pasta.

With regard to cooking time, most studies [2, 13, 15-18, 21] verified the optimal cooking time by compressing the cooked sample between two glass slides every 30 seconds, until the central axis disappeared, according to the American Association Cereal Chemistry method (AACC). The longest cooking pasta (15 minutes) was made with quinoa by Kirinus, *et al.* [2], but the author reports as a positive aspect that 50g less quinoa flour was needed to prepare the pasta, which favored the cost aspect of the product. While the study by Tomicki, *et al.* [21], which used a mixture of rice flour (60g) + cornmeal (40g), had the shortest cooking time (2 minutes), but its mass was served only pre-cooked to the judges.

Gluten-alternative raw materials can add nutritional and functional value such as phenolic compounds and / or higher fiber content when compared to wheat flour. In the study with sorghum flour (40%) + rice flour (20%) + potato starch cornmeal (40%) Ramírez, *et al.* [20] the authors point out that they found protein values close to those obtained in the banana flour dough Zandonadi, *et al.* [18] However, when compared to wheat pasta that has 10g of protein per 100g of mass, its value is still low, in turn the kilocalories are close (378kcal) [14] compared to wheat (371kcal) [26].

Some studies, such as Tomicki, *et al.* [21], which used rice flour and cornmeal and Ferreira, *et al.* [14] who used rice flour, sorghum, corn and potato starch obtained higher lipid values in their samples, probably due to the use of oil and / or eggs in their formulations.

Tomicki, *et al.* [21] made noodles with rice flour and corn. The protein results of its final product were 7g.100g^{-1}, almost equivalent to the cornmeal dough prepared by Paiva, *et al.* [17], who obtained 6.22g.100g^{-1} of protein, ie rice flour did not interfere with the protein value of the pasta nor did the pasta of the mixture [23] obtain higher carbohydrate values which was 80.31g.100g^{-1} compared to 52.5g.100g^{-1}.

Regarding fiber, the mass with cornmeal [17] reached 2.08g.100g^{-1}, while the mixture of rice flour and corn [21] reached 0.67g.100g^{-1}. The wheat noodle has 2.9g.100g^{-1} fiber, in this sense the pasta that not only reached, but also surpassed that value was made with flaxseed Moura [16] that obtained 19.83g.100g^{-1} of pasta.

Flaxseed has 28% of dietary fiber, with a good proportion of soluble and insoluble, which justifies this high value of fiber in pasta, and is also rich in lipids that are mostly composed of polyunsaturated fatty acids [16].

In the legume group, studies were found with soybean [2, 13], lentil [10], pea [10, 22] and chickpeas [10, 12]. Soybean is a raw material of great interest for the preparation of pasta due to its various technological properties, such as emulsifying action, stabilizer, gelatinization capacity, elasticity, cohesion and aeration. It is rich in high quality proteins and contains substances such as isoflavones, fibers and sterols that have functional properties [27]. Its addition to the masses obtained high scores in the color aspect, since soybean confers a yellow color that is generally well accepted in masses and likewise obtained good acceptance in the flavor aspect when author Kirinus, *et al.* [2] separated her.

Studies in which several formulations had been performed, the proportion of raw materials referred by the authors as those with the best results in the tests was chosen [14, 21].

Thus, this study allowed the identification of several raw materials that are used for the substitution of wheat in the preparation of pasta and other types of pasta, which has favored the food industry to meet the demands of segments of the population for products free from gluten, whether for physiological or lifestyle reasons, but excluding gluten from traditionally wheat-based products is still a challenge for the market, as the sensory characteristics conferred by it have not yet been presented by any other grain or seed for bakery products.

4. Conclusion

In light of the findings of the present review, it is clear that currently the range of ingredients that can be used for wheat substitution has increased considerably due to the researchers' efforts to find substitutes for this cereal that may help in the formation of a gluten-like structure, as well as provide greater nutritional support to the masses.

The most used raw material to replace wheat was rice, followed by corn. The average cooking time was 8.75 minutes and most masses had good acceptability.

In this context, it is expected that studies will continue to be carried out in order to offer more possibilities of ingredients that give the product characteristics as close as possible to those offered by gluten and that are sensorial accepted by the population.

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