Phenolic Compounds in Functional Pasta

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Phenolic compounds are lost during the refining of flour and semolina, hence commonly consumed pasta is not a carrier of these components. Consumption of food products rich in phenolic compounds has been associated to reduced risk of chronic disease onset. Hence, several strategies have been developed to formulate functional pasta rich in phenolic compounds.

Whole grain, legume and composite flours are the main substituents of durum wheat semolina used for this purpose. Plant by-products from industrial food wastes have been also used as functional ingredients. In addition, pre-processing technologies on raw materials such as sprouting, or the modulation of extrusion/extrusion-cooking conditions, are valuable approaches to increase phenolic content in pasta.

Keywords: phenolic compounds ; bioactive compounds ; functional pasta ; gluten-free pasta ; whole grain ; composite flour ; legumes ; agri-food waste

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1. Introduction

Pasta is a healthy food. It is a good source of carbohydrates and energy. Daily consumed pasta is not a carrier of phenolic compounds, since it is produced with refined flour or semolina. Most bioactive compounds are concentrated in the outer layers of cereal grains which are discarded as bran, hence, phenolic compounds are commonly lost during milling.

In recent years, scientists and producers have been striving to develop new formulas, so that pasta can, not only provide nutrients and energy, but also beneficially modulate one or more targeted functions in the body, by enhancing a certain physiological response and/or reducing the risk of disease [1]. These new formulations are known as functional pasta products.

The use of functional ingredients, such as whole grain and composite flours, as well as the addition of extracts from plant foods and food wastes, has been increasingly explored as a strategy to improve phenolic content in pasta and gluten-free pasta. In addition, processing technologies have been specifically applied to raw materials or to the pasta-making process in order to increase the content of bioactive components and their bioavailability.

2. Use of Functional Ingredients in Pasta-Making

2.1. Whole Grain Flours

In whole grain flours, the outer multi-layered skin (bran) is retained, and this fraction is a major source of phenolic acids [2].

The content of phenolic compounds in whole grain pasta has been poorly investigated. In precooked pasta prepared from whole grain wheat and whole grain spelt, phenolic acids were determined [3]. Compared to refined flours, the use of whole flours enabled to double the intake of these components.

Also in whole grain spaghetti, TPC level was 2-fold higher than in regular ones [4]. However, TPC significantly decreased after cooking (about 40%), both in regular and whole wheat spaghetti.

2.2. Composite Flours

Composite flours are blends of wheat and varying proportion of legumes, tubers or other cereals, including minor cereals, and pseudocereals. Blends of cereal flours with pulse flours have been by far explored in pasta-making.

In pasta formulated with wheat semolina and 35% faba bean (Vicia faba L.) flour, TPC increased from 63.8 mg Gallic Acid Equivalents (GAE)/100 g dry matter (dm) to 185.3 mg GAE/100 g dm [5]. In functional pasta with varying proportions of wheat (T. durum L.) semolina, chickpea flour, and chia flour, the highest phenolic content (approximately 16 mg GAE/g) was observed when durum semolina was totally replaced and a blend of 10% chia flour and 90% chickpea flour was used. This value was approximately 8-fold higher than in durum wheat pasta (2 mg GAE/g) [6]. In pasta produced with varying percentages of carob flour (1–5%), phenolic content was higher in enriched pasta than in the control [7].

Pseudocereal flours were also used to partially or totally replace semolina in pasta-making, in order to enhance pasta nutritional profile. Varying levels of amaranth seed flours and dried amaranth leaves (35%, 50%, 55% and 70%) were used as semolina substituents in the preparation of elbow-type pasta [8]. The highest value was observed in pasta with a semolina:amaranth flour/leaves ratio of 65:35. A significant decrease in phenolic content (15–27%) was observed in all amaranth pasta samples, after cooking [8].

Composite flours have been also used to improve the nutritional value of gluten-free (GF) pasta. Different percentages of blue maize (25%, 50% and 75%) were added to pasta dough produced with equal amounts of unripe plantain and chickpea flour [9]. It was observed that pasta samples containing 75% of blue maize presented the highest TPC retention after extrusion and cooking. Upon extrusion, TPC in pasta decreased between 20% and 30%, while an additional 10% loss occurred upon cooking.

The fortification of traditional GF flours with sorghum (Sorghum bicolor (L.) Moench) flour in pasta-making has been also studied. GF pasta was produced with white and brown sorghum [10]. Total phenolic compound content was higher in the two sorghum-based pasta samples than in the controls. Sorghum pasta, after cooking, also showed higher radical scavenging activity and ferric reducing ability than the control samples, without significant differences between sorghum varieties.

2.3. Powders and Extracts from Plant Foods and Food By-Products

The use of powders and extracts from plant foods and food by-products in pasta-making is among the strategies recently explored to obtain functional pasta, both gluten-containing and gluten-free.

Functional pasta was prepared by incorporating carrot powder (10%), mango peel powder (5%), moringa leaves powder (3%) and defatted soy flour (15%) in a blend of wheat semolina and pearl-millet [11].The addition of mango peel powder and moringa leaves powder provided the highest total flavonoid content (TFC) values, while carrot powder and defatted soy flour contributed at a lower extent.

The contribution of mushroom powder addition to the phenolic content of spaghetti was also explored [12]. Three different powders from white button, from shiitake and from porcini mushrooms were used, at three different substitution levels. It emerged that all mushroom-powder-supplemented pasta samples had TPC values significantly higher than semolina pasta, except for 5% and 10% shiitake mushroom pasta. The greatest values were found in porcini mushroom pasta samples.

Agri-food waste has been also used as a source of phenolic compounds. Onion dry skin powder has been applied in pasta-making [13]. Pasta added with onion skin powder showed TPC and TFC higher than the control (100% semolina pasta). The highest TPC was found in pasta with 7.5% substitution level. Moreover, cooked pasta showed TPC not significantly different from the corresponding raw sample, whichever addition level of onion skin powder.

Durum spaghetti were formulated by the addition of olive paste powder [14]. In spaghetti added with 10% of olive paste flour, TPC was 4-fold higher than in the control pasta. HPLC analysis also showed that the addition of olive paste powder increased the content of flavonoids, such as quercetin and luteolin.

Functional spaghetti were also produced by addition of extracts from grape marc, made up of skins, seeds, and stalks [15]. The addition of grape marc extract increased TPC in all enriched spaghetti samples. Interestingly, after cooking an increase in TPC was observed, with respect to the raw samples.

Bran is the main by-product of cereal milling and is a great source of phenolic compounds and minerals. Recently, bran aqueous extract was used in the production of spaghetti [16] and a significant increase in phenolic compounds was observed.

As regards the formulation of functional gluten-free (GF) pasta, different percentages of chia (Salvia hispanica L.) milled seeds were incorporated into rice flour dough [17]. Chia seed addition allowed increasing phenolic acid content.

The phenolic profile of GF pasta prepared with a blend of rice and field bean flour, enriched with different amounts of pear prickly fruit (Opuntia ficus indica (L.) Mill.) was determined [18]. HPLC-ESI-MS/MS showed that pasta samples formulated with the different amounts of pear prickly fruit were rich in several phenolic acids: protocatechuic, caffeic, syryngic, 4-OHbenzoic, vanilic, gentisic, trans-sinapic, cis-sinapic, p-coumaric, ferulic, isoferulic, m-coumaric, 3,4-dimetoxycinnamic, and salicylic acids.

The effect of chestnut fruit (Castanea sativa Mill.) addition to the aforesaid blend of rice and field bean flour on pasta phenolic content, was also investigated [19]. It was observed that the total content of free phenolic acids increased along with the chestnut addition.

3. Raw Material Processing, Pasta-Making and Pasta Cooking

In addition to the use of raw materials naturally rich in phenolic compounds, modulation of raw material processing and pasta-making and pasta cooking parameters has been explored to increase the content of phenolic compounds in pasta.

Debranning, also known as pearling, is a technology based on the gradual removal of the outer bran layers prior to milling process. Semolina and flour obtained by debranning are richer in components commonly found in the grain aleurone. The technology also enables to isolate aleurone-rich fractions, which can be used as functional ingredients [20]. Pasta enriched with a debranning fraction from purple wheat has been recently formulated [21]. Despite the debranning technology enabled to obtain raw materials rich in phenolic compounds, pasta samples showed TPC lower than it was expected. This was possibly due to the degradation of phenolics during the pasta-making process, especially in the drying step.

Two functional pasta products enriched with a fraction obtained from either the first or the second debranning step of purple wheat were produced [22]. Anthocyanin content in functional pasta was higher than in pasta added with bran and used as control sample.

Spaghetti were formulated with debranning fractions of durum wheat [23]. As regards raw samples, free phenolic acid (PA) content was higher in the control than in functional pasta, while conjugated and bound PAs were higher in the enriched samples. After cooking, a higher level of PAs was observed in enriched pasta. Conversely, free and conjugated TPC decreased, and bound TPC increased.

Micronized fractions were also explored in pasta-making [23]. Raw pasta prepared from debranned and micronized durum wheat had a higher level of PAs (conjugated and bound) and total phenolics (TPs) than the control. After cooking, the level of free and conjugated PAs increased, while bound PAs decreased.

In addition to mechanical treatments, biological processes, such as germination and fermentation, are strategies enabling to increase the phenolic compound content in pasta products.

As regards germination, both cereal grains and pulses can be sprouted. Sprouted cereals were used in pasta-making [24]. In detail, spaghetti were formulated by replacing wheat semolina with 30% dry tartary buckwheat sprouts. TPC in both raw and cooked samples of tartary buckwheat spaghetti was higher than in 100% semolina spaghetti. Flours from sprouted legumes have been also used in pasta-making. Pasta prepared with sprouted chickpea flour had phenolic content 15% higher than non-sprouted chickpea pasta [25].

The pasta-making process can also influence the content of phenolic compounds; process parameters and conditions may be thus set in order to limit/avoid phenolic compound degradation and/or increase their bioaccessibility.

As regards the effect of extrusion-cooking parameters on phenolic content in pasta, the application of higher screw speed enabled to obtain higher phenolic content in GF precooked rice-yellow pea pasta [26]. The effect of extruder screw speed on free phenolic acid content of GF precooked pasta obtained from roasted buckwheat (Fagopyrum esculentum Moench and F. tataricum Gaertner) flour was investigated [27].

Cooking may also influence the content of phenolic compounds and/or change the ratio between free and bound form of phenolics. Total Phenolic Acids were not greatly affected by this treatment in barley pasta, and both free and bound phenolic compounds were preserved [28]. Conversely, an increase in the content of the free forms was observed. Also in gluten-free pasta, an increase in free phenolic compounds was observed after cooking [29].

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