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Effect of fruit pomace on pasta properties

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Abstract

Reducing food waste is a top priority in efforts to develop sustainable food systems. Agro-food byproducts have the potential to be valued by becoming functional food ingredients because they are rich in valuable compounds such as proteins, fatty acids, vitamins, minerals, and dietary fibre. One of the most widely consumed foods in the world, pasta is a great way to get nutrients into your diet. When high-quality ingredients made from agro-industrial waste are added to pasta recipes, the nutritional profile of the pasta is improved and several health benefits are conferred. This review thoroughly investigates the various aspects of adding fruit pomace to pasta, exploring how it affects the product's nutritional value, phytochemical composition, structural integrity, thermal stability, and functional qualities. The potential of fruit pomace, an underutilised byproduct that is high in dietary fibre, antioxidants, and bioactive compounds, as a functional ingredient in pasta formulations is being studied. This review systematically evaluates the impact of different fruit pomace varieties on pasta properties, such as texture, colour, cooking characteristics, and nutritional enrichment, by synthesising and analysing the existing research. The summary of results clarifies the extent and potential of fruit pomace as a workable component to enhance the nutritional profile and texture of pasta, opening the door for creative recipes that meet changing consumer demands for more enticing and healthful food options.

Keywords: Agro-food by-product, fruit pomace, dietary fibre, pasta, phytochemicals, functional properties

Introduction

Food waste has become a serious global problem that affects not only the economy but also the environment and public health, especially when it comes to fruits and vegetables. These food products are very perishable and vulnerable to quality loss at every level of manufacturing, resulting in large losses while being a valuable source of biologically active chemicals (Kaur *et al*., 2022) [1]. Approximately 30% of the food produced for human consumption is wasted annually, with fruits and vegetables being among the most affected, according to the Food and Agriculture Organisation (Kultys *et al*., 2022) [2]. The waste produced during fruit and vegetable processing, such as the pomace from juice manufacturing, which is defined by high amounts of valuable bioactive chemicals, nevertheless has a great deal of potential for use. In order to achieve sustainable food consumption and production, as described in the agenda 2030 Sustainable Development Goals, it is imperative to address food waste, particularly in the context of fruit and vegetable waste. Food waste has substantial effects on the economy, the environment, and society (Galkowska *et al*., 2022) [3].

A healthy, balanced diet must include fruits and vegetables in particular since they provide vital nutrients, vitamins, and minerals. But the loss of these perishable goods during production, shipping, and storage not only threatens food security but also wastes resources and causes producers and farmers to suffer financial losses (Chusak *et al*., 2020) [4]. Fortunately, there are a number of methods that can help the fruit and vegetable business cut down on food waste. These include enhancing harvesting practises, optimising storage and delivery settings, using cutting-edge packaging techniques, and encouraging food recovery and redistribution programmes. Additionally, there is significant interest in the valorisation of fruit and vegetable waste through the creation of new products with added value, such as functional components, dietary supplements, and animal feed (Santis *et al*., 2022) [5].

Fruit pomace, a byproduct of fruit processing, is a rich source of many biologically active substances, including sugars, vitamins, proteins, lipids, pectins, organic acids, fibre, and mineral compounds. Fruit pomace has a lot of potential as a nutrient-rich raw material for further processing, despite its high-water content, which may help to slow the growth of microbes (Namir *et al*., 2022) [6]. Additionally, the wrong way to dispose of it might pollute the environment. As a result, fruit pomace can be seen as a valuable resource for the food industry, and careful processing can aid in the creation of novel and long-lasting food products. In order to maximise the value of this by-product, this article will examine the potential of fruit pomace as a valuable raw material for the food sector. It will also highlight the nutritional advantages of this by-product and describe the best processing methods (Saad *et al*., 2021) [7].

Pasta has been around since ancient China, making it one of the most popular dishes worldwide. Its popularity can be due to how simple it is to prepare, how versatile it is, and how inexpensive it is to produce, making it affordable for every home. Depending on the components used in its preparation, pasta's nutritional value varies, with egg pasta having a higher protein content than semolina-based pasta (Boff *et al*., 2022) [8]. Researchers have looked into a number of strategies to improve the nutritional content of pasta, including using gluten-free ingredients. In order to produce a high-quality product, it is necessary to alter the production technology because this may affect the product's structure and quality. Pasta that has been properly made should have a consistent, creamy or light-yellow colour, a smooth, crack-free surface, and a distinct scent. Pasta should have a volume increase of two to three times when it is cooked. Pasta is normally made by combining flour, water, and occasionally eggs to create a dough that is then rolled out and cut into different forms. Pasta comes in a broad variety of shapes, ranging from long, thin spaghetti to small, tubular penne (Tolve *et al*., 2020) [9].

The type of flour used in the manufacturing of pasta affects its nutritional content. For instance, whole wheat pasta has more fibre and minerals than pasta prepared with refined flour. In order to improve the nutritional content of their pasta, several producers also add veggies like spinach or beetroot to it (Difonzo *et al*., 2021) [10]. In conclusion, pasta is a well-liked and adaptable dish that has been relished for decades. By using whole wheat flour or including veggies in the pasta dough, you can boost the nutritional content of the dish. The desired texture and flavour of pasta dishes must be achieved through the use of proper cooking methods (Simonato *et al*., 2019) [11].

The sustainability of the system can be considerably improved by using leftover fruit and vegetable items when making juice. The waste generated during the juice making process is very nutrient-dense and useful for other purposes. Pomace, the remaining fruit or vegetable pulp, is added to pasta products to reduce food waste and improve the nutritional content of the pasta. Additionally, the effect of pomace addition on the cooking and textural characteristics of pasta was investigated. Fruit and vegetable pomace are used more frequently in the food sector as ingredients for bread, biscuits, and increasingly pasta. By decreasing waste and improving the nutritious content of food products, this strategy improves sustainability (Nguyen *et al*., 2023) [12]. The aim of this study is to investigate the effect of fruit pomace on pasta properties.

Nutritional and phytochemical significance of fruit pomace

Fruit pomaces are intermediate products that are obtained, particularly in the wineries and fruit processing industries, by pressing or crushing whole fruits to extract their juice (Erinle *et al*., 2022) [13]. Apples, carrots, oranges, berries, and other fruits have all been used to make juice, with significant volumes of pomace being created once the juice is extracted. Fruit pomace undergo oxidation and fermentation reactions practically immediately after processing in the presence of oxidants, light, and heat, which can damage important components inside them (Gowman *et al*., 2019) [14]. However, the disposal problem might be resolved with the right processing, such as drying the pomace after juice extraction. Fruit pomaces often consist of the fruit's skin, peel, and remaining seeds as well as the stalk or stem. Reports have shown that the available amount of pomace in orange, apple, carrot, berries, and grape include 45%-60%, 25%, 30%-50%, 20%-30%, and 20%-25%, respectively (O'Shea *et al*., 2015; Struck *et al*., 2016; Yu *et al*., 2018; Gowman *et al*., 2019) [80, 81, 82, 14].

Fruit pomace is a rich source of vitamins, minerals, phytochemicals, and/or polymeric substances such lignocellulose compounds and pectin. Antioxidant substances called phytochemicals, like phenolics and carotenoids, can lessen the risk of serious chronic diseases by preventing oxidative stress brought on by oxidation. Because antioxidant chemicals stop lipid peroxidation, they can make food products more stable (Struck *et al*., 2020) [20]. Due to its high moisture content (up to 50%), fresh fruit pomace is susceptible to microbial deterioration. Consequently, to produce fruit pomace powder with a high concentration of bioactive components, suitable processing, such as ideal drying, milling, and conditioning, is required. In addition, the process of micronizing fruit pomace has the potential to improve the extraction of phenolic compounds, boost its antioxidant capacity, and alter its dietary fibre content by elevating the soluble dietary fraction. All of these benefits could lead to an increase in the utilisation of fruit pomace as functional ingredients in the food industry (Santos *et al*., 2022) [16].

Because of their advantages for the environment, human health, and the economy, it is imperative that these minerals and bioactive substances (pectin, fibre, polyphenols, antioxidants, and vitamins) be extracted from fruit pomace. Because these derived bioactive chemicals have potent anti-inflammatory, antioxidant, anti-allergenic, and anti-cancer characteristics, they have a positive impact on health by regulating the human body's metabolic and cellular activities (Iqbal *et al*., 2021) [17].

Due to its high dietary fibre content, low-cost, high-water binding capacity, and relatively limited enzyme digestibility, fruit pomace is a suitable source of dietary fibre. Juices from a variety of fruits and vegetables can be extracted, and the leftover waste can be used to recover phytochemicals and dietary fibre that can then be added to food products. Due to their physiological significance in promoting health and their ability to impart techno-functional qualities in food matrices, dietary fibres are powerful food ingredients that can be used as innovative ingredients for the valorisation of food products (Sahni *et al*., 2018) [18]. Dietary fibre has a positive impact on human health because it is largely composed of hemicellulose, cellulose, lignin, oligosaccharides, pectins, gums, and waxes. It also resists hydrolysis by human digestive enzymes and ferments either fully or partially in the large intestine. 20–35 grammes of dietary fibre should be consumed daily by a healthy person. Diverticulosis, cancer, heart disease, and constipation are linked to inadequate dietary fibre intake. High-dietary-fiber diets have been shown to help prevent, reduce, and treat conditions like diabetes, colon cancer, and coronary heart disease. Furthermore, dietary fibre tends to reduce the digestion of fat (Mishra *et al*., 2020)

[19].

Fruit pomaces are a well-known source of sugars, minerals, dietary fibre, organic acids, and bioactive substances like phenolic compounds. Phenolics are a highly diverse group of secondary plant metabolites that include tannins, lignans, lignins, coumarins, flavonoids, stilbenes, flavonolignans, and simple phenolic acids (derived from benzoic and cinnamic acid), (Liu *et al*., 2022) [20]. Numerous phenolic compounds have demonstrated potent antioxidant capabilities as metal chelating agents, oxygen scavengers, peroxide decomposers, and free radical inhibitors. In addition to their antioxidant properties, phenolic compounds also possess antitubercular, antiviral, antibacterial, cardioprotective, and antimutagenic properties (Nirmal *et al*., 2023) [23]. Because these are high-value products and their recovery may be financially attractive, new aspects regarding the use of these wastes as by-products for further exploitation on the production of food additives or supplements with high nutritional value have thus gained increasing attention.

Table 1: Chemical composition of fruit pomace

Composition	Unit	Observation	Reference
Protein	%	8.01±0.06	(Luca *et al*., 2022) [22]
Fat	%	1.01±0.03	
Ash	%	5.89±0.02	
Fiber	%	33.34±0.25	
Moisture Content	%	3.78±0.01	
Carbohydrates	%	48.00±0.24	
Energy	Kcal/100g	333.96±47.87	

Effect of fruit pomace on nutritional properties

Fruit pomace composition and amount of nutrients and polyphenols vary based on a number of parameters, such as the kind of fruit, cultivar, and maybe edapho-climatic circumstances of the harvest site. Since the concentration levels of phenolic components in different fruit pomace varies, total phenolic content (TPC) and antioxidant assay would be adequate to estimate their effectiveness (Erinle *et al*., 2022) [13]. By adding 5–10% lyophilized olive pomace to durum wheat semolina, (Simonato *et al*., 2019) [11] created spaghetti with useful properties. The amount of total phenolic content and antioxidant capacity of the pasta were considerably impacted by the by-product incorporation. Due to its DF (48% w/w) and phenolic content, olive pomace has the intriguing ability to influence starch digestibility, resulting in a drop in RDS and an increase in SDS. According to the authors, instead of polyphenols inhibiting a-amylase and a-glucosidase activities, which would slow down the pace of starch digestion, DF could compete with starch granules for water adsorption, restricting the starch gelatinization. Furthermore, there is considerable interest in the DF content of olive pomace. The total DF content and antioxidant capacity of the pasta increased significantly by approximately 608 and 132%, respectively, with the addition of 20% dried and milled carrot pomace, which is composed of peel, shavings, and peduncles. What's interesting is the 388% increase in retinol found in the cooked pasta made with carrot flour when compared to pasta made with commercial b-carotene (Porto Dalla Costa *et al*., 2016) [25].

Tolve *et al*. (2020) [9] substituted durum wheat semolina at 5 and 10% in pasta manufacturing with grape pomace, a byproduct of winemaking. Nutritionally speaking, the addition of grape pomace to the fortification resulted in a notable rise in the amount of phenolic compounds and antioxidant activity. These compounds were linked to the presence of epicatechin, rutin, quercetin, kaempferol, and resveratrol, as well as gallic, ferulic, coumaric, rosmarinic, and caffeic acid (Gaita *et al*., 2020) [27]. Furthermore, assertions regarding the benefits of grape pomace-fortified pasta are supported by the high DF concentration. Last but not least, pasta enriched with 10% grape pomace showed a rise in SDS and a fall in RDS, positively affecting the predicted glycaemic index (pGI). Consequently, the glycaemic index of pasta decreased from 57.5 (control pasta) to 53.2 (addition of 15% grape pomace). When (Sykut-Domanska *et al*., 2020) [28] evaluated the impact of fortifying pasta with two distinct coconut by-products (coconut flour and coconut residue), they found that the inclusion of more by-products led to a progressive increase in the pasta's ash, protein, lipid, total, and insoluble DF. However, compared to pasta treated with coconut flour, the pasta supplemented with coconut residue had higher levels of protein, total, and insoluble DF.

The addition of apple peel powder resulted in a notable rise in total phenolic compounds (TPC) and antioxidant capability. The addition of 15% apple peel powder resulted in the greatest increase in TPC (1.4 g of GAE/kg) and antioxidant capacity (0.8 mg gallic acid equivalents/100 g) (Loncarićc *et al*., 2014) [49]. Furthermore, (Padalino *et al*., 2017) [30] found that substituting tomato peel flour for up to 15% of durum semolina in pasta resulted in a considerable increase in carotenoids (lycopene and b-carotene) and DF (soluble and insoluble). The antioxidant, sensory, and cooking qualities of pasta enhanced with berries were investigated by (Bustos *et al*., 2019) [31]. They used freeze-dried and air-dried blackberry, raspberry, and black and red currant powder in place of some of the regular wheat flour. Pasta's polyphenol and anthocyanin contents rose as a result of this enrichment. As a result, there was an increase in antioxidant activity in the enhanced product. Pasta enhanced with berries was thought to be excellent, firm, and fruity. In order to make conventional wheat pasta, (Biernacka *et al*., 2020) [32] partially substituted banana powder for wheat flour. Compared to the control product, the enriched product exhibited improved antioxidant characteristics and a higher level of total phenolics (ABTS assay and DPPH (2, 2-diphenyl-1-picrylhydrazyl) assay). Furthermore, when ripe banana flour was added to pasta, other scientists discovered that the pasta was more resistant to enzyme digestion than when it was not fortified.

The bio accessibility of polyphenols and starch digestion of durum wheat pasta enhanced with persimmon flour derived from *Diospyros kaki* fruit were investigated by (Lucas-González *et al*., 2015) [83]. This tropical fruit, which is a member of the Ebenaceae family, is rich in flavonoids, proanthocyanin, tannins, and catechins. Pasta's polyphenolic profile was altered by the addition of persimmon flour; the enriched pasta showed the presence of p-coumaric-o-hexoside and gallic acid in particular. However, after adding persimmon flour, the amount of phenolic chemicals in the raw pasta remained unchanged. Furthermore, the addition of persimmon flour did not enhance the low bio accessibility of polyphenols in pasta. Additionally, the cooked pasta displayed a lower free polyphenol content and a lower antioxidant activity (ABTS assay) in relation to the proportion of free phenolics. Significantly, following the pasta-digestion process, ABTS values rose in direct proportion to the persimmon flour content. Remarkably, adding 3% persimmon flour slowed down the starch digestion's kinetics; yet, adding 6% persimmon flour had no such effect. Pasta made with regular wheat was mixed with powdered Gac fruit (*Momordica cochinchinensis*), both ripe and unripe. It was discovered that pasta enhanced with ripe fruit powder contained carotenoids such lutein, zeaxanthin, β-cryptoxanthin, α-carotene, and β-carotene. Additionally, compared to the control product, the enriched pasta had a roughly two-fold greater amount of total phenolics and a four-fold higher antioxidant activity (FRAP, or ferric reducing antioxidant power) assay. It's interesting to note that boiling reduced the amount of carotenoids but had no discernible effect on the amount of total phenolics or antioxidant activity. Furthermore, the use of both ripe and unripe Gac flour in place of wheat flour reduced the amount of carbohydrates and nearly doubled the overall fat content (Chusak *et al*., 2020) [4].

Pureeing fruits and vegetables and mixing them with wheat flour or semolina is an intriguing way to fortify pasta. Since the pureed material is put directly, this pasta enrichment method is economically justified (without drying). When making pasta, mixed freshly blanched and pulped Syzygium cumini fruit straight into the semolina. This fruit has a high level of antioxidant activity, a wealth of minerals, and several pharmacological properties. They found that the enriched pasta exhibited higher levels of antioxidant activity (DPPH radical scavenging activity) and total phenolic content. When 40% fruit pulp was added to control pasta, the phenolic content rose from 111.2 mg GAE (gallic acid equivalent)/g dry matter (d.m.) to 176.3 mg GAE/g d.m. Additionally, the pasta's fibre content increased by around threefold, and its water solubility and absorption indices both rose (from 7.0% to 9.33% and 1.65 to 2.38, respectively).

In conclusion, adding fruit pomace to durum wheat pasta is an intriguing new trend that will make pasta products more appealing to consumers by improving their sensory qualities and adding more nutritional and healthful benefits. Additionally, it frequently raises the bioavailability of starch, which raises the glycaemic index of pasta. However, this kind of pasta enrichment alters the gluten network and increases the starch granules' water absorption. Pasta's sensory qualities and cooking quality are frequently negatively impacted by these alterations. As a result, before adding any ingredient to pasta, its level must be properly estimated (Dziki *et al*., 2021) [36].

Effect of fruit pomace on structural and thermal properties

There are noticeable structural alterations when fruit pomace is added to pasta formulation. Pomace alters the way gluten interacts with other proteins, which could change the pasta's texture and elasticity. The density and bite of the pasta can change depending on the kind and amount of pomace used, which can also affect how it tastes overall (Bianchi *et al*., 2021) [37]. Additionally, adding pomace could change the pasta's porosity, which would affect how well it absorbs water when cooking. As a result, this may result in variations in pasta cooking times and texture, requiring modifications to hydration levels and processing methods in order to preserve the appropriate consistency (Wang *et al*., 2022) [38].

Fruit pomace addition affects the sensory qualities and practical qualities of pasta in addition to its nutritional value. There is a noticeable difference in the pasta's texture and look. Fruit pomace has the ability to change the final product's hardness, chewiness, and overall mouthfeel (Boff *et al*., 2022) [8]. Additionally, this inclusion may alter the rheology of the dough and its ability to absorb water during the preparation process, which may affect the pasta's ultimate texture and cooking durations. In order to ensure consumer pleasure and market acceptance, these adjustments require a careful balance in formulation to preserve the pasta's intended features without compromising its taste or texture (Desai *et al*., 2018) [40].

Fruit pomace is a major ingredient that changes the structural composition and texture of pasta. It adds more fibre and may have an impact on gluten interactions, which could affect the pasta's elasticity and cooking properties. The fruit used may add different amounts of moisture to the dough, which could affect how the dough handles during processing and how the cooked product is cooked. Hydration levels and processing methods adjustments are frequently necessary to keep the pasta at the desired consistency and cooking performance (Bianchi *et al*., 2021) [37]. The two primary metrics used to assess the textural qualities of pasta are adhesiveness and hardness. The most popular technique for evaluating the cooked pasta's texture profile is the Texture Profile Analysis, which makes use of a texture analyser. Usually, to simulate the act of chewing, the Texture evaluation entails coming into contact with cooked to the best pasta samples, packing them, and moving returning to the initial point of contact and going through the complete cycle again (Bustos *et al*., 2015) [42]. The definition of firmness or hardness is the power necessary to use teeth to pierce the pasta samples and indicates the level of resistance to the initial bite. (Marti *et al*., 2014) [43]. Pasta using tomato peel flour (Padalino *et al*., 2017; Padalino *et al*., 2019) [30, 45], grape pomace (Tolve *et al*., 2021) [37], coconut residue (Sykut-Domanska *et al*., 2020) [28], showed a higher firmness than control. This was likely owing to the stiff structure of the DF particle in these functional ingredients added. Tudorica *et al*. (2002) [48] proposed a relationship between pasta hardness and the hydration/gelatinization of starch granules during cooking. Therefore, the decrease in firmness could be linked to a drop in the amount of starch in the enriched pasta as well as an increase in the gelatinization of pasta starch.

The addition of apple peel powder, grape marc aqueous extract, and coconut and kimchi by-products decreased adhesiveness, which is defined as the negative peak force needed to separate the texture analyser's probe from the pasta sample surface (Loncaric *et al*., 2014; Marinelli *et al*., 2015; Kim *et al*., 2017; Sykut-Domanska *et al*., 2020) [49, 50, 51, 28]. This is likely due to the action of DF from added ingredients, which encouraged the breakdown of the gluten network (Tudorica *et al*., 2002) [48]. However, adhesiveness rose as dietary fibre content did in pasta fortified with olive by-products. According to the authors, a rise in firmness may result from an increase in fibre content, whereas a rise in adhesiveness may be caused by a high absorption of water (Simonato *et al*., 2019) [11]. The rheological characteristics of pasta dough are impacted by the addition of fruit pomace. It may alter the dough's extensibility, elasticity, and viscosity, which may affect how easy it is to handle while being processed. Processing method changes or the addition of binding agents may be required to preserve the dough's workability and consistency (Karim *et al*., 2023) [53]. High hygroscopicity soluble fibres typically compete with protein and starch for water when they hydrate, resulting in partially encased starch in the protein matrix. This can create a "starchy" layer on the product's surface, increasing adhesiveness. Additionally, the addition of high-fibre ingredients to the pasta gluten matrix weakens it, which increases the adhesiveness of samples due to starch leaching (Tudorica *et al*., 2002) [48]. Rakhesh *et al*. (2015) [54] emphasised that the textural properties of pasta are affected differently by various sources of fibre (such as guar gum and inulin). Furthermore, the author came to the conclusion that interactions between protein, starch, and fibres at the microscopic and molecular levels are likely what govern how fibres influence the textural qualities of pasta.

Pasta's thermal behaviour during cooking is greatly influenced by fruit pomace. Its presence may have an effect on the starch's ability to gelatinize, influencing the firmness and cooking time of the pasta. These changes in thermal characteristics may also affect how the pasta cooks, requiring adjustments to cooking temperatures or times to get the right firmness and texture (Leonard *et al*., 2020) [55].

There are various obstacles to overcome in order to incorporate fruit pomace while maintaining the appropriate structural and thermal properties. Carefully adjusting the recipe is necessary to preserve the pasta's texture, colour, and cooking qualities. For the pasta to have a consistent texture throughout, the pomace must be distributed evenly throughout the dough. Determining the ideal amount, kind, and processing conditions for fruit pomace is essential to achieving the required structural and thermal qualities without sacrificing the pasta's overall quality. This involves fully comprehending the interactions between fruit pomace and other pasta ingredients. To ensure consistent product quality, this process entails optimising the pomace to other ingredient ratio, fine-tuning processing parameters, and possibly using binding agents or additives (Dey *et al*., 2021) [56].

A careful balance must be struck when adding fruit pomace to pasta recipes in order to enrich it nutritionally without sacrificing the pasta's flavour, texture, or structural integrity. Furthermore, in order to attain the intended functional and sensory results, it is essential to comprehend the unique qualities of various fruit pomace varieties and how they interact with pasta ingredients.

Effect of fruit pomace on functional properties

Fruit pomace integration in pasta making has several advantages over traditional pasta formulations. Above all, fruit pomace is a nutritional powerhouse that adds fibre, important vitamins, and antioxidants to pasta. This infusion improves the nutritional profile of the pasta by providing important elements contained in fruits and supporting digestive health because of its high fibre content. Furthermore, the natural pigments found in fruit pomace offer an appealing visual element, giving the pasta vivid colours and maybe increasing its market appeal, particularly for consumers who are health-conscious and looking for more nutrient-dense options (Rachman *et al*., 2020) [57]. Determining the functional characteristics is crucial in defining the quality of pasta. A number of factors need to be taken into account for a proper evaluation of pasta technology, including pasta colour, texture, and cooking.

The ideal cooking time, cooking loss, water absorption index, and swelling index are the cooking properties that are used to evaluate the quality of pasta (Nilusha *et al*., 2019) [58]. After pasta is produced, one of the first technological parameters to be assessed is the optimum cooking time (OCT), which is the amount of time needed to see the pasta's centre disappear when it is gently squeezed between two glass slides. OCT is typically observed to decrease following pasta fortification. For example, OCT was found to be lower in pasta containing onion skin powder (Michalak-Majewska *et al*., 2020) and olive and grape pomace (Tolve *et al*., 2020) [9]. This decrease in OCT is likely caused by the increased dietary fibre (DF) content, which changes the structure of pasta, speeds up water penetration, and permits an early starch gelatinization.

Cooking loss (CL) is another crucial factor to consider when evaluating pasta quality. The ability of the gluten network to hold onto starch granules and bioactive compounds during cooking processes is what determines low cooking loss, which indicates high quality pasta (Nilusha *et al*., 2019) [58]. CL is measured by the release of solids from pasta into cooking water (AACC, 2000) [60]. Pasta fortified with by-products has generally been demonstrated to have a higher CL when compared to control pasta. According to (Marinelli *et al*., 2015) [50], spaghetti that had grape marc aqueous extract added had lower CL. They also proposed that the antioxidant compounds in the extract may have formed complexes with gluten protein, resulting in a more uniform gluten network and fewer cooking losses. Ho *et al*. (2016) [62] observed the same outcome in noodles fortified with watermelon rind. The possibility that watermelon fibres and starch competed for water absorption to stop the starch granules from leaching and reduce adhesiveness was discussed by the authors.

Pasta that has been cooked to perfection absorbs a certain amount of water (WA), which is linked to the swelling index (SI), a measure of the integrity of the protein matrix, and starch swelling and gelatinization. A weaker gluten network promotes the growth of starch granules WA and accelerates the process of gelatinization, leading to a rise in SI. Without the addition of extra ingredients, high-quality pasta typically has a SI of about 1.8 and a WA of 150–200 g of water/100 g of pasta (Bustos *et al*., 2015) [42].

The distinctive yellow colour of durum wheat semolina, which is attributed to its high carotenoid content, is one of the key characteristics that characterises pasta quality. Colour is incredibly significant and has a big impact on the decision that customers make. The new pasta formulations' colour could be significantly altered by the addition of additional ingredients (Bustos *et al*., 2015) [42]. L* a* b* values, which are related to the CIELAB colour space, are used to express colour. The perceptual lightness is represented by L*, the red/green value by a*, and the blue/yellow value by b*. The L* value typically dropped following pasta fortification.

The addition of grape pomace, apple peel powder, mango peel powder, and DF from kimchi, respectively, was found to reduce the lightness (L*) of pasta (Tolve *et al*., 2020; Loncarićc *et al*., 2014; Jalgaonkar *et al*., 2018; Kim *et al*., 2017) [9, 49, 66, 51]. Rather, pasta fortified with coconut flour and orange fibre has been found to have an increase in L* value (Crizel *et al*., 2015; Sykut-Domanska *et al*., 2020) [68, 28]. Pasta fortified with grape pomace and mango peel powder increased in a* and b* values, according to findings from other researchers (Jalgaonkar *et al*., 2018; Tolve *et al*., 2020) [66, 9]. On the other hand, adding powdered watermelon and apple peels resulted in a decrease of the same values (Loncarićc *et al*., 2014; Ho *et al*., 2016) [49, 62]. While it is evident that the inclusion of by-products in pasta needs to be carefully considered in terms of colour changes and consumer acceptability, this may also depend on differences in consumer perceptions worldwide.

Along with elasticity, firmness, bulkiness, and adhesiveness, some of the most significant sensory characteristics of pasta are appearance, colour, and flavour (Marinelli *et al*., 2015) [50]. According to Sykut-Domanska *et al*. (2020) [28], the pasta's sensory profile in terms of surface appeal, colour, smell, taste, hardness, stickiness, and overall acceptability was unaffected by the addition of coconut flour and coconut residue up to 15% and 10%, respectively. According to Tolve *et al*. (2020) [9], adding grape pomace considerably decreased certain pasta attributes like colour and aroma while increasing the aroma, acidity, and astringency of the wine. A high fibre content in pasta can cause the protein-starch network to be disrupted, reducing its elasticity, and increasing its firmness as a result of the fibres' absorption of water (Tudorica *et al*., 2002) [48]. The profile of pasta was greatly impacted by the substitution of olive by-products for durum wheat semolina in terms of elasticity, firmness, and bulkiness because of the strength of the gluten network, as well as adhesiveness and colour (Cedola *et al*., 2020) [69].

According to Crizel *et al*. (2015) [68], the sensory assessment of pasta enhanced with orange by-product revealed that the taste and aftertaste changed to the point where consumers were less accepting of the product at higher levels of incorporation. Because orange seed and peel were used to prepare the fibre, the presence of bitter compounds like naringin, nobiletin, quercetin, and tangeretin may have contributed to the low scores for these attributes (Drewnowski *et al*., 2000) [70]. According to Porto Dalla Costa *et al*. (2016) [25], the inclusion of carrot flour by-product had no impact on the acceptability parameters.

The product obtained may differ significantly from the control, either meeting or failing to meet the expectations of the consumer, depending on the type of by-product and its sensory characteristics, taking into account the composition and concentration used (Bianchi *et al*., 2021) [37]. A careful balance must be struck when adding fruit pomace to pasta recipes in order to enrich it nutritionally without sacrificing the pasta's flavour, texture, or structural integrity. Furthermore, in order to attain the intended functional and sensory results, it is essential to comprehend the unique qualities of various fruit pomace varieties and how they interact with pasta ingredients.

Table 2: Functional properties of fruit pomace

Functional properties	Unit	Observation	Reference
Hydration capacity	%	66.81±2.24	(Luca *et al*., 2022) [22]
Water absorption capacity	%	15.96±0.44	
Oil absorption capacity	%	34.72±0.85	
Water retention capacity	g/g	5.33±0.05	
Foaming capacity	%	7.00±0.00	
Foaming stability	%	94.00±0.00	
Swelling capacity	mL/g	25.96±0.01	
Bulk density	g/cm³	0.46±0.00	

Applications

Fruit pomaces, the leftovers from fruit processing, are now a main attraction in many different industries, one of which is pasta making. When added to pasta dough, these byproducts—which come from fruits like citrus, grapes, and apples—offer a variety of advantages. They are nutritional powerhouses first and foremost, adding dietary fibre, antioxidants, vitamins, and minerals to pasta. This fortification offers a healthier substitute for regular pasta by increasing the pasta's functional qualities and raising its health quotient (Piasecka *et al*., 2020) [72].

In addition, fruit pomaces give pasta's texture and appearance a delightful twist. Apple pomace, for example, adds a hint of granularity, and berry or grape pomaces add bright colours and delicate fruity notes. This addition of colour and texture results in a wider variety of pasta products that are more aesthetically pleasing and sensory-diverse.

Fruit pomace can be used to gluten-free pasta recipes, particularly when it comes from tropical fruits like mangos and bananas. They contribute to the cohesiveness of ingredients and provide a pleasing flavour without sacrificing texture (Dziki *et al*., 2021) [36]. Pomace can add a distinct twist to classic pasta dishes by infusing pasta with subtle or pronounced fruit flavours, depending on the type of fruit used. Orange or lemon pomace, for example, can add a zesty note that balances the flavour profile overall (Singla *et al*., 2021) [75].

Consider the possibilities of pomace berries, such as those from raspberries, blueberries, or strawberries. These fruit scraps, full of natural pigments and antioxidants, give pasta a subtle fruity essence in addition to a pop of colour. This infusion serves customers looking for distinctive flavour experiences in addition to broadening the pasta market (Santis *et al*., 2022) [5]. Moreover, the use of fruit pomace in pasta production goes beyond nutrition and flavour. It is essential for meeting the growing demand for functional foods. For example, adding pomaces with high concentrations of bioactive compounds—like the flavonoids or polyphenols found in a variety of fruit leftovers—can help create pasta that may have health benefits. These substances may have additional health benefits beyond those of regular pasta because they have been linked to anti-inflammatory and antioxidative qualities (Gumul *et al*., 2023) [77].

Fruit pomace can be added directly to pasta dough or used as an ingredient in pasta coatings and fillings. Dried fruit pomace coatings or fillings can add distinctive flavours and textures to pasta products, allowing producers to produce a wide variety of pasta products that meet changing consumer tastes.

Fruit pomace integration supports sustainability goals by repurposing waste from fruit processing, which goes beyond texture and nutrition. By recycling what would otherwise be thrown away, this practise encourages a more environmentally conscious approach within the food industry and supports a circular economy. In addition, these pomaceous fruits are essential for improving the functional qualities of pasta because they contain natural compounds like pectin, which promote improved texture, moisture retention, and overall cooking performance (Struck *et al*., 2020) [20].

Though the advantages seem promising, adding fruit pomace to pasta calls for a careful balance. In order to guarantee consistent quality, formulation challenges arise in finding the ideal balance of taste, texture, and processing methods. Furthermore, the market success of these innovative pasta variations depends on consumer acceptance, which calls for careful consideration of preferences and perceptions to foster widespread adoption. However, using fruit pomace in pasta production is a novel and sustainable approach that provides distinct tastes, improved nutritional value, and a step towards a more ecologically conscious food industry (Carpentieri *et al*., 2022) [79].

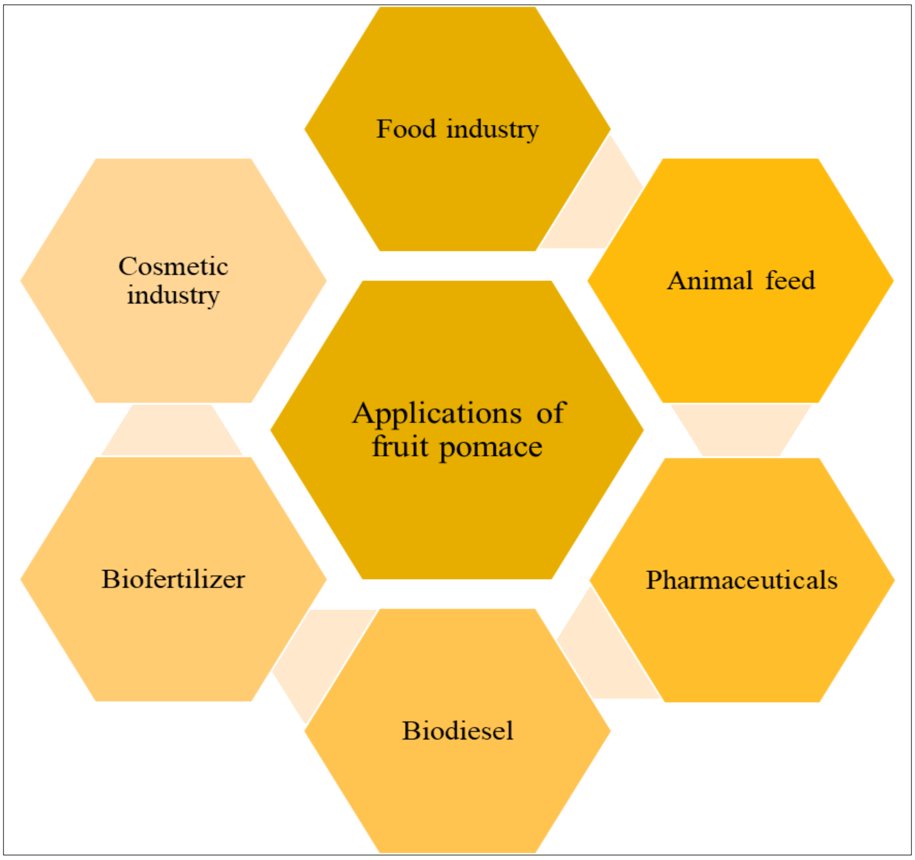

Fig 1: Applications of fruit pomace

Conclusion

Pasta is a staple food that is high in carbohydrates but low in proteins and other beneficial ingredients. However, pasta that has been enhanced with ingredients that have a high added value can serve as a great nutritional carrier. For this reason, scientists developed novel pasta recipes that made use of components sourced from agricultural and industrial waste. In fact, a lot of food waste contain bioactive substances that can increase pasta's nutritional value and satisfy consumer demands. The incorporation of fruit pomace into the process of making pasta demonstrates the vibrant collaboration that exists between nutrition, sustainability, and creative cooking. Whether they are grape, apple, citrus, berry, or tropical fruit byproducts, these fruit processing byproducts add a variety of features to pasta. They improve pasta's nutritional value, texture, colour, and flavour profile, giving customers a more satisfying pasta experience.

However, fortification can have an impact on the technological characteristics of pasta, primarily due to the fact that new ingredients—especially those high in fibre—have the ability to change the gluten matrix and, as a result, the structure of the pasta. Thus, it would seem to be crucial to have a thorough understanding of how various types of fibre, as well as the interaction between soluble and insoluble fibre, affect the texture and cooking qualities of pasta. Further research on the effects of protein, starch, and phenolic compounds on the textural and digestibility characteristics of pasta—as well as how these interactions affect the fortified product's glycaemic index—would also be beneficial from a microstructural perspective. The acceptability of the new formulation pasta is largely dependent on how much fortification is added.

This symbiotic relationship between fruit remnants and pasta production not only reduces food waste but also paves the way for a more innovative, health-conscious, and environmentally conscious culinary landscape. Finally, the production of innovative pasta recipes using ingredients derived from industrial byproducts fits within the framework of sustainability and circular economy.

References

1. Kaur M, Dhaliwal M, Kaur H, Singh M, Punia Bangar S, Kumar M, *et al*. Preparation of antioxidant-rich tricolor pasta using microwave processed orange pomace and cucumber peel powder: A study on nutraceutical, textural, color, and sensory attributes. J Texture Stud. 2022;53(6):834-843.
2. Kultys E, Moczkowska-Wyrwisz M. Effect of using carrot pomace and beetroot-apple pomace on physicochemical and sensory properties of pasta. Lwt. 2022;168:113858.
3. Gałkowska D, Witczak T, Pycia K. Quality characteristics of novel pasta enriched with non-extruded and extruded blackcurrant pomace. Molecules. 2022;27(23):8616.
4. Chusak C, Chanbunyawat P, Chumnumduang P, Chantarasinlapin P, Suantawee T, Adisakwattana S, *et al*. Effect of gac fruit (*Momordica cochinchinensis*) powder on *in vitro* starch digestibility, nutritional quality, textural and sensory characteristics of pasta. Lwt. 2020;118:108856.
5. De Santis D, Ferri S, Rossi A, Frisoni R, Turchetti G. By-product of raspberry juice as a functional ingredient: effects on the properties and qualitative characteristics of enriched pasta. Int J Food Sci Technol. 2022;57(12):7720-7730.

6. Namir M, Iskander A, Alyamani A, Sayed-Ahmed ETA, Saad AM, Elsahy K, *et al*. Upgrading common wheat pasta by fiber-rich fraction of potato peel byproduct at different particle sizes: Effects on physicochemical, thermal, and sensory properties. Molecules. 2022;27(9):2868.
7. Saad AM, El-Saadony MT, Mohamed AS, Ahmed AI, Sitohy MZ. Impact of cucumber pomace fortification on the nutritional, sensorial and technological quality of soft wheat flour-based noodles. Int J Food Sci Technol. 2021;56(7):3255-3268.
8. Boff JM, Strasburg VJ, Ferrari GT, de Oliveira Schmidt H, Manfroi V, de Oliveira VR, *et al*. Chemical, technological, and sensory quality of pasta and bakery products made with the addition of grape pomace flour. Foods. 2022;11(23):3812.
9. Tolve R, Pasini G, Vignale F, Favati F, Simonato B. Effect of grape pomace addition on the technological, sensory, and nutritional properties of durum wheat pasta. Foods. 2020;9(3):354.
10. Difonzo G, Troilo M, Squeo G, Pasqualone A, Caponio F. Functional compounds from olive pomace to obtain high-added value foods–a review. J Sci Food Agric. 2021;101(1):15-26.
11. Simonato B, Trevisan S, Tolve R, Favati F, Pasini G. Pasta fortification with olive pomace: Effects on the technological characteristics and nutritional properties. Lwt. 2019;114:108368.
12. Nguyen TPT, Tran TTT, Ton NMN, Le VV. Use of Cashew Apple Pomace Powder in Pasta Making: Effects of Powder Ratio on the Product Quality. Pol J Food Nutr Sci. 2023;73(1):50-58.
13. Erinle TJ, Adewole DI. Fruit pomaces—their nutrient and bioactive components, effects on growth and health of poultry species, and possible optimization techniques. Anim Nutr. 2022;9:357-377.
14. Gowman AC, Picard MC, Rodriguez-Uribe A, Misra M, Khalil H, Thimmanagari M, *et al*. Physicochemical analysis of apple and grape pomaces. BioRes. 2019;14(2):3210-3230.
15. Struck S, Rohm H. Fruit processing byproducts as food ingredients, in Valorization of Fruit Processing By-products, Elsevier; c2020. p. 1-16.
16. Santos LF, Lopes ST, Nazari MT, Biduski B, Pinto VZ, Santos JSD, *et al*. Fruit pomace as a promising source to obtain biocompounds with antibacterial activity. Crit Rev Food Sci Nutr; c2022. p. 1-13.
17. Iqbal A, Schulz P, Rizvi SS. Valorization of bioactive compounds in fruit pomace from agro-fruit industries: Present Insights and future challenges. Food Biosci. 2021;44:101384.
18. Sahni P, Shere DM. Utilization of fruit and vegetable pomace as functional ingredient in bakery products: A review. Asian J Dairy Food Res. 2018;37(3):202-211.
19. Mishra A, Poonia A. Phytochemicals from the Fruits and Vegetable Waste: Holistic and Sustainable Approach. Sustainable Food Waste Management: Concepts and Innovations; c2020. p. 87-112.
20. Liu S, Lou Y, Li Y, Zhang J, Li P, Yang B, *et al*. Review of phytochemical and nutritional characteristics and food applications of *Citrus* L. fruits. Front Nutr. 2022;9:968604.
21. Nirmal NP, Khanashyam AC, Mundanat AS, Shah K, Babu KS, Thorakkattu P, *et al*. Valorization of Fruit Waste for Bioactive Compounds and Their Applications in the Food Industry. Foods. 2023;12(3):556.
22. Luca MI, Ungureanu-Iuga M, Mironeasa S. Carrot Pomace Characterization for Application in Cereal-Based Products. Appl Sci. 2022;12(16):7989.
23. Erinle TJ, Adewole DI. Fruit pomaces—their nutrient and bioactive components, effects on growth and health of poultry species, and possible optimization techniques. Anim Nutr. 2022;9:357-377.
24. Simonato B, Trevisan S, Tolve R, Favati F, Pasini G. Pasta fortification with olive pomace: Effects on the technological characteristics and nutritional properties. Lwt. 2019;114:108368.
25. Porto Dalla Costa A, Cruz Silveira Thys R, De Oliveira Rios A, Hickmann Flores S. Carrot flour from minimally processed residue as substitute of b-carotene commercial in dry pasta prepared with common wheat (*Triticum aestivum*). J Food Qual. 2016;39:590-598.
26. Tolve R, Pasini G, Vignale F, Favati F, Simonato B. Effect of grape pomace addition on the technological, sensory, and nutritional properties of durum wheat pasta. Foods. 2020;9:1-11.
27. Gaita C, Alexa E, Moigradean D, Conforti F, Poiana M-A. Designing of high value-added pasta formulas by incorporation of grape pomace skins. Romanian Biotechnological Letters. 2020;25:1607-1614.
28. Sykut-Domanska E, Zarzycki P, Sobota A. The potential use of by-products from coconut industry for production of pasta. J Food Process Preserv. 2020;44:1-9.
29. Loncaric A, Kosovic I, Jukic M, Ugarcic Z, Pilizota V. Effect of apple by-product as a supplement on antioxidant activity and quality parameters of pasta. Croat J Food Sci Technol. 2014;6:97-103.
30. Padalino L, Conte A, Lecce L. Functional pasta with tomato by-product as a source of antioxidant compounds and dietary fibre. Czech J Food Sci. 2017;35:48-56.
31. Bustos MC, Paesani C, Quiroga F, León AE. Technological and sensorial quality of berry-enriched pasta. Cereal Chem. 2019;96:967-976.
32. Biernacka B, Dziki D, Różyło R, Gawlik-Dziki U. Banana powder as an additive to common wheat pasta. Foods. 2020;9:53.
33. Butt MS, Sultan MT, Aziz M, Naz A, Ahmed W, Kumar N, Imran M, *et al*. Persimmon (*Diospyros kaki*) fruit: Hidden phytochemicals and health claims. EXCLI J. 2015;14:542-561.
34. Chusak C, Chanbunyawat P, Chumnumduang P, Chantarasinlapin P, Suantawee T, *et al*. Effect of gac fruit (*Momordica cochinchinensis*) powder on *in vitro* starch digestibility, nutritional quality, textural and sensory characteristics of pasta. LWT Food Sci. Technol. 2020;118:108856.
35. Ahmed S, Ahmed KS, Hossain MS, Azam MS, Rahman M, Hoque MM, *et al*. Proximate composition and antioxidant activity of syzygium cumini fruit grown at different regions in Bangladesh. Food Res. 2020;4:1693-1699.
36. Dziki D. Current trends in enrichment of wheat pasta: Quality, nutritional value and antioxidant properties. Processes. 2021;9(8):1280.
37. Bianchi F, Tolve R, Rainero G, Bordiga M, Brennan CS, Simonato B, *et al*. Technological, nutritional and sensory

properties of pasta fortified with agro-industrial by-products: a review. Int J Food Sci Technol. 2021;56(9):4356-4366.

38. Wang J, Brennan MA, Serventi L, Brennan CS. Impact of functional vegetable ingredients on the technical and nutritional quality of pasta. Crit Rev Food Sci Nutr. 2022;62(22):6069-6080.
39. Boff JM, Strasburg VJ, Ferrari GT, de Oliveira Schmidt H, Manfroi V, de Oliveira VR, *et al*. Chemical, technological, and sensory quality of pasta and bakery products made with the addition of grape pomace flour. Foods. 2022;11(23):3812.
40. Desai A, Brennan MA, Brennan CS. The effect of semolina replacement with protein powder from fish (*Pseudophycis bachus*) on the physicochemical characteristics of pasta. LWT - Food Sci Technol. 2018;89:52-57.
41. Bianchi F, Tolve R, Rainero G, Bordiga M, Brennan CS, Simonato B, *et al*. Technological, nutritional and sensory properties of pasta fortified with agro-industrial by-products: a review. Int J Food Sci Technol. 2021;56(9):4356-4366.
42. Bustos MC, Perez GT, Leon AE. Structure and quality of pasta enriched with functional ingredients. RSC Advances. 2015;5:30780-30792.
43. Marti A, Pagani MA, Seetharaman K. Textural attributes of wheat and gluten-free pasta. In: Food texture design and optimization. YL Dar & JM Light, eds. New York: John Wiley & Sons; c2014. p. 222-224.
44. Padalino L, Conte A, Lecce L. Functional pasta with tomato by-product as a source of antioxidant compounds and dietary fibre. Czech J Food Sci. 2017;35:48-56.
45. Padalino L, Costa C, Del Nobile MA, Conte A. Extract of Salicornia europaea in fresh pasta to enhance phenolic compounds and antioxidant activity. Int J Food Sci Technol. 2019;54:3051-3057.
46. Tolve R, Simonato B, Rainero G, Bianchi F, Rizzi C, Cervini MG, *et al*. Wheat Bread Fortification by Grape Pomace Powder. 2021:1-12.
47. Sykut-Domanska E, Zarzycki P, Sobota A. The potential use of by-products from coconut industry for production of pasta. J Food Process Preserv. 2020;44:1-9.
48. Tudorică CM, Kuri V, Brennan CS. Nutritional and physicochemical characteristics of dietary fiber enriched pasta. J Agric Food Chem. 2002;50:347-356.
49. Loncaric A, Kosovic I, Jukic M, Ugarcic Z, Pilizota V. Effect of apple by-product as a supplement on antioxidant activity and quality parameters of pasta. Croat J Food Sci Technol. 2014;6:97-103.
50. Marinelli V, Padalino L, Nardiello D, Del Nobile MA, Conte A. New approach to enrich pasta with polyphenols from grape marc. J Chem. 2015;2015:1-8.
51. Kim BR, Kim S, Bae GS, Chang MB, Moon BK. Quality characteristics of common wheat fresh noodle with insoluble dietary fiber from kimchi by-product. LWT - Food Sci Technol. 2017;85:240-245.
52. Simonato B, Trevisan S, Tolve R, Favati F, Pasini G. Pasta fortification with olive pomace: Effects on the technological characteristics and nutritional properties. LWT. 2019;114:108368.
53. Karim A, Raji Z, Habibi Y, Khalloufi S. A review on the hydration properties of dietary fibers derived from food waste and their interactions with other ingredients: Opportunities and challenges for their application in the food industry. Crit Rev Food Sci Nutr; c2023. p. 1-35.
54. Rakhesh N, Fellows CM, Sissons M. Evaluation of the technological and sensory properties of durum wheat spaghetti enriched with different dietary fibres. J Sci Food Agric. 2015;95:2-11.
55. Leonard W, Zhang P, Ying D, Fang Z. Application of extrusion technology in plant food processing by-products: An overview. Compr Rev Food Sci Food Saf. 2020;19(1):218-246.
56. Dey D, Richter JK, Ek P, Gu BJ, Ganjyal GM. Utilization of food processing by-products in extrusion processing: A review. Front Sustain Food Syst. 2021;4:603751.
57. Rachman A, Brennan MA, Morton J, Brennan CS. Gluten-free pasta production from banana and cassava flours with egg white protein and soy protein addition. Int J Food Sci Technol. 2020;55:3053-3060.
58. Nilusha RAT, Jayasinghe JMJ, Perera ODAN, Perera PIP. Development of pasta products with nonconventional ingredients and their effect on selected quality characteristics: A brief overview. Int J Food Sci. 2019;2019:1-10.
59. Michalak-Majewska M, Teterycz D, Muszynski S, Radzki W, Sykut-Domanska E. Influence of onion skin powder on nutritional and quality attributes of wheat pasta. PLoS One. 2020;15:1-15.
60. AACC. Approved Method of the AACC. 10th edn. St. Paul, MN: Edited by American Association of Cereal Chemists; c2000.
61. Marinelli V, Padalino L, Nardiello D, Del Nobile MA, Conte A. New approach to enrich pasta with polyphenols from grape marc. J Chem. 2015;2015:1-8.
62. Ho LH, Che Dahri N. Effect of watermelon rind powder on physicochemical, textural, and sensory properties of wet yellow noodles. CyTA – J Food. 2016;14:465-472.
63. Bustos MC, Perez GT, Leon AE. Structure and quality of pasta enriched with functional ingredients. RSC Advances. 2015;5:30780-30792.
64. Tolve R, Pasini G, Vignale F, Favati F, Simonato B. Effect of grape pomace addition on the technological, sensory, and nutritional properties of durum wheat pasta. Foods. 2020;9:1-11.
65. Loncaric A, Kosovic I, Jukic M, Ugarcic Z, Pilizota V. Effect of apple by-product as a supplement on antioxidant activity and quality parameters of pasta. Croat J Food Sci Technol. 2014;6:97-103.
66. Jalgaonkar K, Jha SK, Mahawar MK. Influence of incorporating defatted soy flour, carrot powder, mango peel powder, and moringa leaves powder on quality characteristics of wheat semolina-pearl millet pasta. J Food Process Preserv. 2018;42:1-11.
67. Kim BR, Kim S, Bae GS, Chang MB, Moon BK. Quality characteristics of common wheat fresh noodle with insoluble dietary fiber from kimchi by-product. LWT – Food Sci Technol. 2017;85:240-245.
68. Crizel TM, Rios AO, Thys RCS, Flores SH. Effects of orange by-product fiber incorporation on the functional and technological properties of pasta. Food Sci Technol. 2015;35:546-551.
69. Cedola A, Cardinali A, D'Antuono I, Conte A, Del Nobile MA. Cereal foods fortified with by-products from the olive oil industry. Food Biosci. 2020;33:100490.
70. Drewnowski A, Gomez-Carneros C. Bitter taste,

phytonutrients, and the consumer: A review. Am J Clin Nutr. 2000;72:1424-1435.

71. Porto Dalla Costa A, Cruz Silveira Thys R, De Oliveira Rios A, Hickmann Flores S. Carrot flour from minimally processed residue as a substitute for β-carotene commercial in dry pasta prepared with common wheat (*Triticum aestivum*). J Food Qual. 2016;39:590-598.
72. Piasecka I, Górska A. Possible uses of fruit pomaces in food technology as a fortifying additive-a review. Zeszyty Problemowe Postępów Nauk Rolniczych; c2020. p. 600.
73. Iuga M, Mironeasa S. Potential of grape byproducts as functional ingredients in baked goods and pasta. Compr Rev Food Sci Food Saf. 2020;19(5):2473-2505.
74. Dziki D. Current trends in enrichment of wheat pasta: Quality, nutritional value and antioxidant properties. Processes. 2021;9(8):1280.
75. Singla G, Panesar PS, Sangwan RS, Krishania M. Enzymatic processing of *Citrus reticulata* (Kinnow) pomace using naringinase and its valorization through preparation of nutritionally enriched pasta. J Food Sci Technol. 2021;58:3853-3860.
76. De Santis D, Ferri S, Rossi A, Frisoni R, Turchetti G. By-product of raspberry juice as a functional ingredient: effects on the properties and qualitative characteristics of enriched pasta. Int J Food Sci Technol. 2022;57(12):7720-7730.
77. Gumul D, Kruczek M, Ivanišová E, Słupski J, Kowalski S. Apple pomace as an ingredient enriching wheat pasta with health-promoting compounds. Foods. 2023;12(4):804.
78. Struck S, Rohm H. Fruit processing by-products as food ingredients. In: Valorization of fruit processing by-products. Academic Press; c2020. p. 1-16.
79. Carpentieri S, Larrea-Wachtendorff D, Donsi F, Ferrari G. Functionalization of pasta through the incorporation of bioactive compounds from agri-food by-products: Fundamentals, opportunities, and drawbacks. Trends Food Sci Technol. 2022;122:49-65.
80. O'Shea K, Nash R. An introduction to convolutional neural networks. arXiv preprint arXiv:1511.08458; c2015 Nov 26.
81. Struck S, Plaza M, Turner C, Rohm H. Berry pomace–a review of processing and chemical analysis of its polyphenols. International Journal of Food Science & Technology. 2016 Jun;51(6):1305-18.
82. Li YH, Yu CY, Li XX, Zhang P, Tang J, Yang Q, *et al*. Therapeutic target database update 2018: enriched resource for facilitating bench-to-clinic research of targeted therapeutics. Nucleic acids research. 2018 Jan 4;46(D1):D1121-7.
83. Romaní-Pérez M, Outeiriño-Iglesias V, Moya CM, Santisteban P, González-Matías LC, Vigo E, *et al*. Activation of the GLP-1 receptor by liraglutide increases ACE2 expression, reversing right ventricle hypertrophy, and improving the production of SP-A and SP-B in the lungs of type 1 diabetes rats. Endocrinology. 2015 Oct 1;156(10):3559-3569.