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THE USE OF TANGERINE PEEL AS A COMPONENT IN FOOD PRODUCTS

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tangerine peel, biologically active substances, food, component, sensory and nutritional properties

ABSTRACT
The information from global literature sources has been summarized regarding the use of ground mandarin peel in the formulation of various food products and beverages. Data on worldwide mandarin cultivation volumes are provided, along with the data on content of carbohydrates, dietary fibers, proteins, various acids, tannins, and ash. Additionally, data on the presence of certain phenolic compounds and monosaccharides in mandarin peel are included. The possibility of using mandarin peel powder due to its high content of dietary fiber and phenolic compounds with antioxidant activity in the formulation of various food products is substantiated. The effect of adding mandarin peel powder to bakery and confectionery products on the functional, baking, textural, antioxidant and sensory properties of wheat bread, grocery and confectionery products made from it has been demonstrated. Additionally, information is provided regarding the use of mandarin peel powder in formulations for the production of meat products (such as cutlets) and dairy products. Data are also presented on adding of mandarin peel powder and its extracts into various beverages and jams. It has been demonstrated that mandarin peel and pomace can be used for the production of both alcoholic and non-alcoholic drinks. It has been shown that adding the mandarin peel powder and its extracts into bakery, confectionery, meat and dairy products, as well as into the formulation of various alcoholic and non-alcoholic beverages, leads to an improvement in the nutritional, nutritious and sensory characteristics of various food products. A conclusion has been made about the prospects of mandarin peel powder as a valuable additive to food products.

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ИСПОЛЬЗОВАНИЕ КОЖУРЫ МАНДАРИНОВ В КАЧЕСТВЕ КОМПОНЕНТА РАЗЛИЧНЫХ ПРОДУКТОВ ПИТАНИЯ

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КЛЮЧЕВЫЕ СЛОВА:
кожура мандаринов, биологически активные вещества, продукты питания, компонент, органолептические и питательные свойства

АННОТАЦИЯ
Обобщены сведения из мировых литературных источников по использованию измельченной кожуры мандарина в рецептуре различных продуктов питания и напитков. Приведены данные по объемам выращивания мандаринов в мире, а также по содержанию углеводов, пищевых волокон, протеинов, различных кислот, таннинов, зольного вещества. Также приведены данные по содержанию некоторых фенольных соединений и моносахаридов в составе кожуры плодов мандаринов. Обоснована возможность использования порошка из кожуры мандаринов ввиду высокого содержание пищевых волокон и фенольных соединений с антиоксидантной активностью в рецептуре различных продуктов питания. Показано влияние добавления порошка кожуры мандаринов в хлебобулочные и кондитерские изделия на функциональные, хлебопекарные, текстурные, антиоксидантные и органолептические свойства пшеничного хлеба, бакалейных и кондитерских изделий из него. Также приведены сведения по использованию порошка из кожуры мандаринов в рецептурах для изготовления мясных (таких как котлеты) и молочных продуктов питания. Приведены сведения по использованию порошка из кожуры мандаринов и экстрактов из него в составе различных напитков и джемов. Показано, что кожура и выжимки мандаринов могут быть использованы для получения алкогольных и безалкогольных напитков. Показано, что введение порошка из кожуры мандарина, а также экстрактов из него в хлебобулочные, кондитерские, мясные и молочные продукты, а также в рецептуру различных алкогольных и безалкогольных напитков приводит к улучшению нутрициологических, питательных и органолептических характеристик различных продуктов питания. Сделан вывод о перспективах порошка мандариновой кожуры как ценной добавки в продукты питания.

1. Introduction

The citrus fruits are the world's third largest cultivated crops after bananas and apples. Citrus trees are widespread commercial garden fruit trees cultivated in industrial scale in the countries with a suitable climate; their fruits (hesperidia) are valued for their palatable characteristics. There are a large number of citrus species of which oranges, lemons, tangerines (also in equal degree called as mandarins), grapefruits, pomelo, etc. which are widely used for human consumption [1]. Tangerines rank second in terms of fructification among citrus fruits, after oranges. The latter have the advantage of the ease of separating the peel from the pulp compared to the fruits of other citrus.

The total gross harvest of tangerines in recent years (the 2025 season) has exceeded 38,14 mln. tons [2]. China is the world's main producer accounting for 27.10 mln. tons, followed by the European Union (2.794 mln. tons), Turkey (2.186 mln. tons), Morocco (1.150 mln. tons), the United States (0.997 mln. tons) and South Africa (1.0 mln. tons) [2].

The fruits of tangerines are mainly used in the food industry for human consumption [3]. Tangerine pulp is also used to make a variety of beverages including juices, jams, marmalades, candied fruits, and other foods. Tangerine pulp separation results in several mln tons of peel generated globally every year [3]. Most of tangerine peel is irrecoverably lost, thus ending up in solid waste landfills, where its rotting contributes to the release of greenhouse gases into the atmosphere.

Recently, the application of fruit and vegetable wastes in various foods has been developing on the global scale [4–13].

It has been determined that tangerine peel is a source of a large number of valuable chemical compounds. Thus, it was determined that raw tangerine peel contains carbohydrates — 80.1 ± 2.87 %, dietary fiber —

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7.21±0.03%, proteins — 4.39±0.02%, various acids — 3.36±0.05%, carotenoids — 2143±25.24 µg/g, tannins — 2±0.2 mg/kg, ascorbic acid-28±1.94 mg/100 g; ash content — 4.92±0.03% [14]. In addition, tangerine peel has been found to contain various polyphenolic compounds [15], polysaccharides [16], and essential oils [17].

Phenolic compounds in citrus peel mainly include phenolic acids, mainly caffeic, *p*-coumaric, ferulic and sinapic, flavonones (naringin and hesperidin) and polymethoxylated flavones (nebiletin and tangeretin). It was found that citrus peel contains more of these compounds than the edible parts of fruits [15]. It was determined that the content of ferulic, p-coumaric, sinapic, caffeic, *p*-hydroxybenzoic, vanillin, and protocatechoic acids in *satsuma* variety of mandarin (*Citrus unshiu* Marc.) peel extracts obtained by 10 minutes' 8W ultrasound treatment at 30°C amounted to 1513.2, 140.8, 132.7, 64.2, 34.1, 34.1, and 15.8 µg/g of dry matter, respectively [15]. At the same time, the total content of gallic acid, hydroxybenzoic acid, vanillic acid, coumaric acid and ferulic acid in *kinnow* variety of mandarin (*Citrus reticulata Var. kinnow*) peel extracts after microwave exposure was 175.22, 72.19, 316.69, 830.27, and 2386.0 µg/g, respectively [18]. The main polyphenolic compounds found in mandarin peel extracts were hesperidin, naringin, tangeridine, and rutin, which accounted for almost 86% of the total amount of extracted phenols [19–21]. Monosaccharides content in *ponkan* variety of mandarin (*Citrus reticulata Blanco cv.Ponkan*) peel hot water extract was found to be as follows: arabinose — 17.7%, mannose — 1.8%, galactose — 17.6%, glucose — 2.9%, rhamnose — 2.7%. The content of uronic acids, proteins, and phenolic compounds was 57.3% [16]. At the same time, Zhang et al. [22] states that the content of arabinose in mandarin peel is 27.5–40.6%, galactose — 4.1–18.5%, rhamnose — 6.2–11.7%, xylose — 10.4%, glucose — 8.9% of the total sugars count. The pectin extracted from tangerine peel showed a total phenolic content of 41.2±1.67 mg GAE/g of pectin. The equivalent weight of pectin was 1950.31±2.78 g/mol, and the content of methoxyls was 11.47±1.21% [23].

Citrus peel including the peel of tangerines contains essential oils with their composition depending on the fruit ripeness, the storage conditions and the extraction method [24]. It contains 85–99% volatile and 1–15% non-volatile components [25]. Citrus peel oil consists of ~97% monoterpenes, alcohols and aldehydes. Esters make up 1.8–2.8% [25]. Due to their excellent antifungal and antibacterial activity, as well as their antioxidant nature, essential oils are used in the preparation and storage of the products with improved storageability [26].

Based on the above, tangerine peel is obviously a valuable secondary material resource and a source of many biologically active substances [27–35]. Figure 1 shows the structure of a tangerine. Based on the above, tangerine peel is considered as a valuable secondary material resource containing biologically active substances and can be used in various food products to increase the nutritional value of the latter [36,37].

2. Objects and methods

The study consists of a detailed analysis of the world and domestic literature on application of crushed or ground peel of mandarin fruits as a component in various food products. The search for literary information was conducted in the Google scholar search engines for 2005–2025. Such a long period contributed to a deeper coverage of literary sources on the topic of the review. Data are provided on the volumes of mandarin cultivation on a global scale and the content of biologically active substances in the peel of the fruit. It is shown that the introduction of mandarin peel powder into various food products helps improving the nutritional, functional and sensory characteristics of food products. The use of mandarin peel and its pomace for the production of alcoholic and soft drinks is also described.

3. The use of tangerine peel in baked goods

Literary sources have found a number of articles about the use of tangerine peel powder (Figure 2) in baking recipes. It was determined that tangerine peel flour contains 34 volatile substances, mainly limonene (58–68%), γ-terpinene (18–22%), β-mercene (2.75–3.1%), terpinolene (1.33–5.36%), α-pinene (1.01–4.74%) and others, the content of which does not exceed 1% [39]. It is stated that tangerine peel flour has a nutrient content that allows its using in food products, since it features high content of dietary fiber and phenolic compounds along with antioxidant activity and is safe from the point of view of microbiological requirements throughout the entire period of use [40].

Thus, there was a study of the quality of sausage bread containing citrus (orange, lime, tangerine and lemon) peel in an amount of 3%. It was determined that sausage bread without citrus peel (control) and a sample with lime peel had the same maximum average score (8.3 points). The bread with tangerine and orange zest had the least score (8.1 points). Physico-chemical analysis data showed that the mass fraction of moisture ranged within 48.08–52.73%, dry matter mass fraction varied within 47.27–51.92%. The remaining quality indicators of the samples were within the normal range [41].

In [42] Kaur et al., *kinnow* peel powder (KPP) was used in a concentration of 0–3% (in terms of flour weight) as a functional ingredient to determine its effect on the functional, baking, textural, antioxidant, and sensory properties of wheat bread. It was found that KPP significantly ($P < 0.05$) reduced the final viscosity of the mixtures and at the same time increased the absorbency during baking by 60.10–67.01% and reduced the cooking loss during baking (14.30–11.16 g). The higher moisture binding and KPP fibers content also reduced the leavening property of bread which resulted in a gradual decrease in the specific volume of the loaf, while at the same time increasing the hardness of the bread crumb (5.41–9.39 N). The presence of biologically active compounds in the powder increased the total content of phenols (16.93–45.21 mg GAE/100 g), flavonoids (4.71–42.53 mg QE/100 g), carotenoids (2.90–6.71 mg/100 g) in bread, and enhanced its antioxidant activity. Experimental bread crumb showed increased lightness and yellowness. Bread with addition of 2% KPP powder showed the best sensory properties and functional characteristics [42].

The nutritional, process, functional, and sensory properties of soup sticks enriched with freeze-dried *kinnow* peel powder (KPP) were also studied. It was determined that an increase in the level of wheat flour substitution with KPP from 0 to 9% resulted a significant increase in ash content, viscoelasticity, tensile strength, yellowness, baking aptitude and storage stability, as well as a decrease in content of moisture, crude protein, crude fat, gelatination degree parameters. In addition, KPP enriched soup sticks showed a longer digestion time compared to that of the control samples and the analysis of the appearance and structure showed a reduction in pores size. Stability analysis during baking and storage revealed the enrichment of soup stick with added KPP with polyphenols. Sensory evaluation showed that an increase in the substitution level had a positive effect on the flavor and color intensity, but worsened the taste [43].

In addition to tangerine peel flour powder, there was a study of the effect of the latter's extracts in wheat bread. Thus, the control bread sample and the sample of wheat bread enriched with 2% and 4% (by weight/volume) tangerine peel extract were analyzed for antioxidant activity and

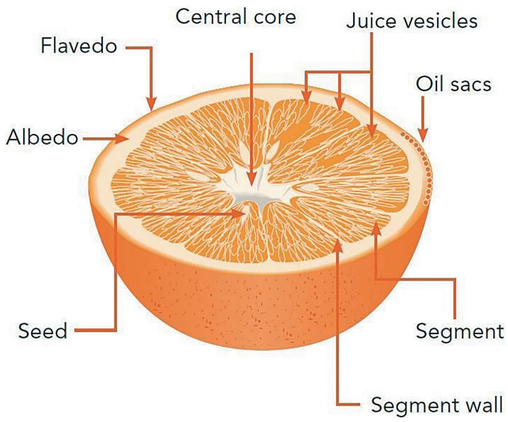

Figure 1. **Cross-section of a mandarin [38]**
Рисунок 1. **Плод мандарина в поперечном разрезе [38]**

Figure 2. **The appearance of mandarin peel powder [40]**
Рисунок 2. **Внешний вид порошка кожуры мандарина [40]**

phenolic composition. Besides, *in vitro* digestion results showed a significant increase in the total content of flavonoids (2.2 ± 0.1 mg/g), antioxidant activity (IC_{50} = 37 ± 4 mg/g), and the content of quercetin, caffeic acid and hesperidin in the 4 % extract-enriched bread. It was revealed that most polyphenols were completely decomposed after *in vitro* digestion process, except for hesperidin (159 ± 36 µg/g), which indicates an increase in the antioxidant potential of bread [44].

4. The use of tangerine peel in biscuits

There are several articles in the international literature about using tangerine peel powder in biscuits recipes [45–55]. Thus, in particular, tangerine peel powder was used in the production of semi-sweet biscuits made from hard dough by replacing wheat flour by 3–9 % of tangerine peel powder to ensure the quality and acceptability of the food product. It was found that the thickness of the biscuits increased during baking, while the width and spread ratio of the biscuits decreased along with an increase in the tangerine peel powder content in the biscuit. It was determined that biscuits containing 6 % of the peel were comparable to the control sample. The content of fiber, ash, ascorbic acid, carotenoids, polyphenols, and antioxidant activity was found to be 0.85 %, 1.32 %, 1.5 mg/100 g, 69 µg/g, 2150 µg of gallic acid equivalent (GAE)/g, and 24.5 %, respectively, which was significantly higher than that of the control sample of the biscuit [46].

Choi in [47], tangerine peel powder was added to biscuits dough in amount of 1–7 %. It was found that the density of biscuit dough, the rate of loss and leavening of biscuits tended to decrease with an increase in the amount of the tangerine peel powder added. The pH of the biscuit dough, moisture content, distribution coefficient, and the lightness of the biscuits decreased, and the redness and yellowness of the biscuits increased significantly along with an increase in the content of tangerine peel powder. The phenolic compounds content and the activity of DPPH-ABTS+ in removing radicals by biscuits increased depending on the amount of citrus peel powder addition. Based on sensory evaluation, biscuits with 3 % tangerine peel ranked first in appearance, texture, and overall preference be the consumers [47].

It was determined that tangerine peel powder has high antioxidant activity and phenolic compounds when added in the amount of 10 % to biscuits. Enriching the crackers with 10 % tangerine peel resulted in an increase in the sensory evaluation of the products. Crackers with tangerine peel showed an improvement in glucose levels, serum lipid profile, hepatic and renal function in experimental animals. The condition of pancreatic tissues in the experimental groups improved compared to the control group. It was concluded that crackers containing 10 % tangerine peel powder had a high potential to increase nutritional value and protect against diabetes [48]. The antioxidant ability, oxidative and sensory stability of biscuits containing tangerine and orange peel powders were studied in [48].

In [49], banana and tangerine peels were finely ground and added to cupcakes and biscuits in concentrations of 3 %, 5 % and 8 %. The samples were analyzed on the day of the cupcakes cooking, as well as after 1, 2, 3 and 5 days of storage. A comprehensive physico-chemical analysis demonstrated an improvement in nutritional and functional properties of the experimental samples compared to the control samples. In particular, the addition of peel powder provided an increase in energy value, improved nutritional qualities due to increasing the protein content (up to 12.8 %), total fat (up to 7.84 %), total carbohydrates (up to 11.4 %), total ash (up to 76.9 %), and total vitamin C content (up to 3.95 times). In addition, fruit peel powder acted as moisture binding agent by reducing moisture content and water activity, thus potentially extending the product's shelf life. Tangerine peel powder featured a more pronounced effect on the physicochemical characteristics compared with the banana peel powder. In addition, the inclusion of powder made of fruit peel significantly increased the levels of total polyphenols, flavonoids, and antioxidant activity, while the values were 2.7 times higher than in the control samples [49].

In [50], wheat flour was replaced with KPP in an amount of 0–15 %. The variable recipe formulations were used to make biscuits. Sensory evaluation showed that the addition of KPP enhanced the aroma, taste and color of the food products. It was revealed that the addition of more than 10 % of KPP powder to the formulation is unacceptable from the point of view of taste. However, the inclusion of the peel significantly increased the fiber and protein content, as well as the ash content of the biscuits. Hence it was concluded that the addition of KPP can enrich biscuits and have a positive effect on their nutritional and sensory qualities [50].

Tangerine peel powder was used to make madeleine biscuits by adding 0–40 % of its mass fraction to flour. It was revealed that the weight and yield of the dough were the highest, and the loss rate was the lowest in the formulation containing 40 % of the tangerine peel powder. The height and volume of the products tended to decrease while increasing the amount of tangerine peel powder added into the formulation. It was found that the biscuits became more bright with increasing the powder concentration, while the yellow and red colors were lowest in the control group and increased as the amount of powder dosage increased. It was determined that the total polyphenols and flavonoids in madeleine biscuits increased significantly as a result of increased amounts of the powder added. The madeleines antioxidant activity also increased with the addition of the powder in a dose-dependent manner. The appearance, aroma, texture, taste, and overall acceptability of the food products were highest with 20 % tangerine peel powder added [51].

Kinnow peel dietary fiber produced by enzymatic extraction with the help of ultrasound was used in the formulation of biscuits. Water-retaining and oil-retaining properties and the ability to absorb fiber glucose were found to be equal to 8.17–9.24 g/g, 2.96–4.68.09 g/g and 1.56–2.28 mmol/g, respectively. It was shown that *kinnow* peel dietary fibers can be used to produce fiber-enriched foods. The extracted fibers were used to develop recipes of biscuits that showed good nutritional, sensory, and textural properties with an overall acceptability index 7.15–7.84 [52].

Kinnow peel and pomace and SFE (supercritical fluid extraction) phytochemicals from the peel were studied to prepare functional biscuits was investigated. Wheat flour was replaced with dried *kinnow* peel and pomace powder at a 5–20 % substitution level, while extracted phytochemicals were added at a 1–4 % substitution level. It was revealed that the enrichment of cookies with *kinnow* waste enhances their nutritional and nutraceutical potential. The inclusion of the phytochemical extract obtained by supercritical fluid extraction of *kinnow* peel allows the production of cookies via more potent bioactive methods than the plain inclusion of *kinnow* peel powder. Natural polyphenols in *kinnow* peel composition have shown excellent ability to improve the shelf life of fortified cookies. The results of researches have shown that cookies prepared with 10 % peel, 5 % pomace and 4 % phytochemicals received the best sensory ratings [53].

5. The use of tangerine peel for making cupcakes and other confectioneries

Along with cookies, tangerine peel powder has also been explored in cupcake recipes [54–61]. In particular, the effect of KPP blanching duration on its physicochemical characteristics and its suitability for cupcake recipes was investigated. Blanching was carried out at 95 °C for 2–8 minutes. It was revealed that with increase of blanching duration pH, bulk density, water absorption index and oil absorption capacity increased and were 6.32, 7.05 g/cm^3, 4.98 g/g and 2.04 g/g, accordingly. It was also determined that increasing the blanching duration had a positive effect on the organoleptic properties and reduced the bitter taste of the KPP. The best consumer properties were observed in cupcakes with 20 % of the KPP added that had been blanched for 8 minutes [56]. Except of blanching duration, effect of particles size onto dough and cupcake parameters was researched. The characteristic of KPP with particle sizes of <180 µm, 180–250 µm and 250–500 µm showed that the particle size of KPP less than 180 µm has higher bulk density, color, oil absorption ability, water solubility and lower water retention capacity. The total phenolic, flavonoid and antioxidant properties of KPP varied within the range 10.1–10.9 mg GAE/g, 4.96–6.09 mg QE/g and 77.5–87.2 %, respectively. Increasing the particle size increased the pasting and thermal properties of the dough. The highest dough pasting viscosity (1069 ± 2 cP) and pasting temperature (75.3 °C) were observed for the KPP with the largest particle size. KPP were introduced into the recipe of cupcakes in the amount of 5–20 % instead of wheat flour. It was found that the increase in the content of KPP in the muffins led to a decrease in volume, color parameters and an increase in hardness. The most sensory and nutritional characteristics were found with the introduction of 5 % of KPP into the recipe of the food product [57].

Tangerine peel powder, tomato pulp, and wheat bran were included in the recipe of cupcakes consisting of soy (25 %) and wheat (75 %) flour, in the ratio of 1:4:8. It was determined that the products had a low acceptability index (68.44 %). The composition of the product was determined as follows: protein content — 15.75 %, fatty acids — 23.55 %, dietary fiber — 13.5 %, carbohydrates — 18.6 %, ash content — 2.27 % and moisture — 26.42 %. It was determined that the food products possessed high antioxidant activity [58].

As well KPP was used to make candies with a long shelf life. In laboratory studies, KPP was processed in nine different ways. The resulting candies were analyzed for their physicochemical and organoleptic properties at intervals of 15 days during 45 days period. The results showed increases in content of crude fiber, total soluble dry matters, pH, reducing sugars, total dry matter and total sugar content as a result of storage. Simultaneously decrease in ash content, moisture, titratable acidity, ascorbic acid content, tannins, antioxidant activity, total phenol content, carotenoids and pectin content was recorded. It was found that the best processing was the method that included repeated boiling, cooking in a 75% sugar syrup solution and leaving in sugar syrup for 24 hours for saturation. The products had the desired approximate physicochemical and organoleptic properties and were stable for at least 45 days of storage [59].

KPP and other ingredients were used for production of nutrition bars. The recipe contained 37% banana pomace flour, 25% of jaggery, 25% of banana peel powder, 10% of KPP and 3% of glycerin. It was determined that the nutritional bar according to the developed recipe had an energy value similar to the commercial bar with low protein and fat content. However, it had more crude fiber (15.14 g/100 g) and minerals such as Ca, K, Fe, Cu and Zn, which could provide 9.5, 29, 40, 18 and 6% of the recommended daily intake, respectively [60].

In the work [60], the sensory and mechanical characteristics, moisture and color indicators of the traditional Korean rice cake "Sulgidduk" with the addition of tangerine peel powder in an amount of 1–4% were analyzed. It was found that the texture of Sulgidduk with the addition of tangerine peel powder, its hardness, elasticity, cohesion and stickiness increased, while stickiness and chewiness had no significant difference. The moisture content of Sulgidduk with mandarin peel powder varied from 37% to 39%. The L value of color decreased along with the increase of mandarin peel powder; however, the *a* value and *b* value of color increased along with the increase of mandarin peel powder added. According to sensory evaluation, the sample with 3% added mandarin powder had the highest values of color and moisture [61].

Conclusion was made about the advisability of using powders of fruit and vegetable pomace as stabilizing additives for fat systems based on vegetable oil, including the production of confectionery emulsions [62].

In work [64], the interaction between fruit powders, the extrusion process, the physical properties and the nutritional quality of the resulting product was studied. The control sample, which included 30% of wheat flour, 25% of corn starch, 25% of potato starch and 20% of dry milk powder, was supplemented with 11% of fruit powder, including tangerine peel. It was found that the addition of fruit powder significantly ($P < 0.05$) affected the expansion and density of extrudates. The content of soluble and insoluble fibers increases significantly after the extrusion process, while antioxidant levels decrease. It was noted that the resulting products (snacks) feature an improved nutritional profile compared to other extruded snacks due to low content of fat and sugar and being a good source of fiber [63].

6. Use of tangerine peel powder in meat and dairy products

Tangerine peel powder was used in recipes for the production of meat and dairy products. Thus, in work [64], the optimal amounts of *Crataegi* fructus flour and dried tangerine peel flour were determined for adding to raw bean flour in a sauce for pork cutlets. By increasing the content of *Crataegi* fructus flour and dried mandarin peel flour in the receipt, the pH value and salinity of the samples decreased, and the DPPH free radical scavenging activity increased. The L value of the samples was 33.37–42.28, the *a* and *b* values did not demonstrate constant trend of behavior. As the content of *Crataegi* fructus flour and dried tangerine peel flour in the receipt increased, the viscosity of the samples increased also. Based on sensory evaluation results, 50–75% of samples received high scores for appearance, taste, color, softness, thickness, and overall acceptability. In conclusion, based on sensory quality and antioxidant properties, the optimal pork cutlet sauce consisted of 50–75% hawthorn fruit flour and dried mandarin peel flour added to raw bean flour [64].

In [65], beef patties were treated with extracts from grape seeds and mandarin pomace at a dosage of 450 µg/g, and compared with control samples for their effect on color, lipid and protein oxidation, and bacterial growth under simulated retail conditions (4 °C) for 9 days, as well as sensory characteristics. It was found that the retail display period had a significant impact on all parameters of the shelf life of cutlets. Overall, the intensity of aroma and taste in beef cutlets was highest in samples containing mandarin pomace extract. The results showed that the extracts could be commercially evaluated as natural antioxidants and antibacterial agents in beef patties [65].

Some physicochemical, microbiological and sensory properties of ice cream produced with addition of essential oils obtained from lemon, tangerine and orange peel in various proportions (0.1%, 0.3% and 0.5%) were investigated. It was found that the pH and acidity values of the samples varied from pH = 6.36–6.45 and 0.22–0.27, respectively. At the end of the study, the lowest total counts of aerobic mesophilic bacteria (3.80 log CFU/g), psychrophilic bacteria (4.01 log CFU/g), yeasts and molds (3.71 log CFU/g) and *Pseudomonas spp*. (2.04 log CFU/g) were detected in the ice cream sample containing orange peel extract. It was found that *coliform* bacteria, *Salmonella* spp., *Staphylococcus aureus, Escherichia coli* and *Listeria* monocytogenes were not detected in any of the ice cream samples. As a result of the sensory evaluation, it was found that the least preferred sample was the control ice cream sample [66].

7. The use of tangerine peel powder in various drinks and jams

As it has been mentioned above, tangerine peel contains essential oil with limonene as the dominant compound, which can be used as a flavoring agent and source of antioxidants in foods. In the work [67], the composition of the recipe, sensory and chemical characteristics of vegetable jam with the addition of encapsulated powder and extract from tangerine peel were determined. The factors used in this study were the type of active substance and the proportion of maltodextrin and gum arabic added in ratios of 1:3–3:1. It was found that the most acceptable is vegetable jam with the addition of encapsulated essential oil extract with a proportion of maltodextrin and gum Arabic in ratio 2:3. It was reported that the sensory assessment for color was 3.67 points, for aroma — 3.53 points, for taste — 3.0 points, and for spreadability — 4.53 points. The water content in the product was 77.32%, the antioxidant activity was 7.75%, the beta-carotene content was 15017.99 µg/100 g, and the total fiber content was 0.62% [67].

Mandarin peel extract was also incorporated into the jam formulation at concentrations ranging from 0.5% to 2.5%. It was observed that the addition of mandarin peel extract at various concentrations significantly influenced the aroma, flavor, and overall preference, but did not significantly affect the color characteristics or lubricity properties of the food product. It was determined that adding 2% of extract to the jam recipe gave the best results for the sensory properties of the jam compared to the control samples. An increase in antioxidant activity from 12.21 to 16.01% was recorded. The product has a color intensity of L — 43.30; a — 3.00; b — 37.03, water content — 58.61%, water activity — 0.73; pH — 3.5 and microorganism content — 3.7×10^3 CFU/g [68]. In addition to jams, the use of mandarin peel is recommended for the production of liqueurs via maceration [69].

Mandarin peel was also used to produce mandarin peel liqueur with three alcohol bases (grain alcohol, sugar cane alcohol and mandarin alcohol). It was determined that the alcohol content was 18.84°, 20.01°, and 19.67° g/l, respectively. Sensory analysis tests were conducted to evaluate the following attributes: alcoholic taste, fruity aroma, sweetness, and overall impression. Grain alcohol-based liqueur showed the highest average value for all attributes (6.32, 6.66, 6.34 and 6.26 points, respectively) [70].

Some food processing wastes (banana, pomegranate, tangerine, eggplant and red onion peels, as well as walnut shells, cherry stems and corn stalks) were used in various compositions and ratios to prepare herbal teas. Three new mixtures were infused at different temperatures (70 and 100 °C) and durations (3, 4 and 5 min). Significant effects of different temperatures and brewing duration on tea color were also demonstrated. Mandarin peel was included in all three herbal mixtures. It was noted that the use of these components in alternative teas may be attractive to the consumers and industrial producers due to their availability and high bioactivity [71].

In the work [72], the protective effect of dry powder based on mandarin peel, hawthorn and *Pueraria lobate* was studied in mice with acute alcoholic liver damage. The optimal process for powder preparation involved soaking three herbs for 30 minutes and performing double extraction. The first solid-liquid ratio was 1 : 12 and the duration of extraction was 2.0 h, and the second was 1 : 10 and the duration of extraction was 1.5 h. Subsequently, the two extracts were combined. After concentration, drying, and grinding, a dry paste-like powder was obtained, which was mixed with maltodextrin in a 1:1 ratio, 1.0% of mogroside and 90% of ethanol were added as wetting agent to enable wet granulation. It was determined that the composite powder made from the extracts has a uniform color, good solubility, moderate sweetness and delicate taste, and also possessed a good hepatoprotective effect in cases of acute alcoholic liver damage [72].

8. Conclusion

Adding mandarin peel powder to various food products, such as bakery products, confectionery, meat and dairy products, helps to improve significantly their nutritional, nutritious and sensory characteristics. The use of this natural component allows enriching food products with vitamins, minerals and biologically active substances, which enriching, in most cases, increases their nutritional value and benefits for the human health. The review also examines the effect of adding tangerine peel powder on the shelf life of the food products and their expiration dates. In most cases, an extension of these parameters was observed.

The above considerations open the new prospects for the utilization of citrus processing wastes in the food industry, thus contributing to the development of innovative technologies and the expansion of the range of natural food products. Generally, results of the study confirm the promising potential of using mandarin peel as an environmentally friendly and functional ingredient, which can contribute to the improvement of food product quality and which meets the demands of the modern consumers for healthy nutrition.

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