Main trends in application of novel natural additives for food production

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Abstract

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Introduction. The review considered the major novel natural additives for food products.

Materials and methods. Analysis of scientific knowledge about novel natural additives for food products has been done.

Results and discussion. In recent years, a lot of research has been conducted to study the application of novel natural additives such as plants with pharmaceutical properties, plant materials with antioxidant activity, essential plants oils, extracts from plant materials seaweeds, seeds products, different gluten-free cereal and pseudo-cereals flours for replacement of gluten in bakery products, dietary fibers, edible coatings materials of plant origins, in preparation of different traditional food products. The main goal of this trend is to improve the health value of these products without significant change of their technological parameters and acceptability by consumers. These new trends include replacement of animal fat by low calorie materials with high content of fatty acids in meat products; use of plant materials with antioxidant properties, for example, extracts from fruits, vegetables, spices, and herbs containing phenolic substances instead of synthetic antioxidants in food preparation; replacement of gluten in bakery products with plant free gluten substitutes; use of plant essential oils as natural preservatives to prolong shelf-life of food products. Some researches concern the application of plant additives with specific pharmacological effect to produce food products useful for prevention of different diseases or supplying the consumers with needed quantities of essential for the health state substances. The present study reviews the main trends in application of novel natural additives used recently in food production.

Conclusions. Review information can be valuable for researchers and managers to prioritize the research and innovation directions in enhancement of food products.

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Introduction

In recent years, a lot of research has been conducted to study novel natural additives to improve the health value of different traditional food products. These new trends include replacement of animal fat by low calorie material with high content of fatty acids in meat products (seed oils, for example); replacement of gluten in bakery products with plant free gluten substitutes; use of addition of plant material with antioxidant properties instead of chemical preservatives to prolong shelf-life of food; an application of edible coating with incorporated natural antioxidant and antimicrobial agents in different food products to protect their properties and extend time of storage. Application of plant additives with specific pharmacological properties was proposed to produce food products useful for prevention of different diseases or supplying the consumers with needed quantities of essential for the health state substances.

The aim of the present study was to review the main trends in application of novel natural additives used recently in food production.

Trend 1. Plant additives with pharmaceutical properties for food products

A new trend in food production is an addition to traditional food products of different plant additives which are used for medical purposes and have pharmacological properties. For example, a tree-shaped plant Bail fruit (*Aegle marmelos* L.), widely distributed in South East Asia, is known as one which has pharmacological properties and traditional medical usage and is also consumed as a food. It was reported that Bael fruit has cardio-protective, radio-protective, gastro-protective and hepato-protective effects, as well as antioxidant, antibacterial, antiviral and anti-diabetic properties (Mulyaningsih et al., 2020; Sarkara et al., 2020; Venthodika et al., 2021). Numerous scientific researches partially along with clinical trials are providing now to establish the ways for usage of *A. marmelos* for different food products such as bael juice, syrups, beverages, jam, toffee, and candy (Mali et al., 2020; Ullikashi et al., 2017). However, pharmacological effects of food products based on bail fruit as well as recommended dosage of its consumption should be studied in further research (Venthodika et al., 2020).

Moringa oleifera is an example of plants with pharmacological properties which are proposed for food preparation (Milla et al., 2021). This plant is considered a source of nutritional and bioactive compounds such as fibres, phenolic compounds, fatty acids, vitamins, minerals and functional peptides, and many authors proposed its application in preparation of functional food products mainly in meats, bakery, juices and sandwiches to improve their nutritional and health value. Only for bakery products, leaf powder from *Moringa oleifera* is proposed to be used for preparation of cookies (Chizoba, 2014), bread (Bolarinwa et al., 2019; Ogunsina et al., 2011; Rabie et al., 2020; Sengev et al., 2013), brownie (Castro-Lopez et al., 2017); rice crackers (Manaois et al., 2013), snack (Devisetti et al., 2015), and cakes (Kolawole et al., 2013).

Lycium plants attract attention by their high nutrition and medicinal value (Jiang et al., 2021). Different parts of *Lyceum* plants, namely berries, leaves and root barks, are used for a long time in traditional Chinese medicine in the treatment of age related diseases such as atherosclerosis and diabetes (Potterat, 2010). Meanwhile, *Lycium* fruit (Goji berries) is widely consumed as a food, for example in Chinese soups and as herbal tea (Ma et al., 2019). Berries, leaves and root barks of *Lycium* plants contain 84 different phenolics (Qian et al.,

2017) and other bioactive substances such polysaccharides and terpenes. *Lycium* fruit can be consumed as dried whole berries and as berries incorporated in meat products, flours and beverages. Addition of *Lycium* berry puree (2.5 and/or 5%) and chia seeds in beef burger increased its antioxidant ability and decreased lipid peroxidation (Antonini et al., 2020). This new product was accepted by consumers as functional burgers. Partially replacement of wheat flour up to 40% with goji berry by-product that is left after production of goji juice/concentrate resulted in significant increase of protein, free phenolic, insoluble and soluble dietary fibers contents in the muffins and cookies (Bora et al., 2019). White chocolate added with *Lycium* berry was positively evaluated by consumers (Ferreira et al., 2017). Incorporation of *Lycium barbarum* berries into yogurt improved it's the antioxidant properties and enriched biological value (Taneva and Zlatev, 2020).

Trend 2. Essential plants oils for food preservation

Application of plant essential oils as natural preservatives is a new trend in food processing. Essential oils are concentrated volatile compounds extracted from different plant materials such as leaves, fruits, flowers, roots, seeds, wood and have been extracted from such plants as sweet orange, lemon, lavender, oregano, rosemary, sage, ginger, clove, cinnamon, curcumin, spearmint, pomegranate peel, grape seed, basil, coriander, garlic cloves, eucalyptus and myrtle. A lot of essential oils are generally recognized as safe (GRAS) and are permitted for use in food products. One of the important properties of essential oils is ability to suppress microbial growth, and this antimicrobial activity could be used in food preservation instead of conventional chemical agents (Hyldgaard et al., 2012). It was shown that tested essential oils had very low minimal inhibitory concentration against different bacteria species estimated as 0.05–60 µg/mL (Aumeeruddy-Elalfi et al., 2015; Bajera et al., 2017). However, the antimicrobial effect of essential oils can be changed and depends on composition of food and used food additives (Garcia-Diez et al., 2017).

It was shown that the addition of the spice nutmeg (*Myristica fragrans*) essential oil in concentration 20 mg/L increased oxidative and microbial stability and extended shelf life of cooked sausages (Sojic et al., 2015). Essential oils as food additives are often used with combinations of other natural preservatives. For example, the addition of *Zataria multiflora* Boiss essential oil and grape extract in quantity 0.1% and 0.2%, respectively, in raw buffalo patties decreased the level of lipid oxidation and extended the shelf life of tested meat products. The presence of essential oil and grape seed extract demonstrated strong antimicrobial effect in raw buffalo patties inoculated with *Listeria monocytogenes* (Tajik et al., 2015). Combination of cinnamon essential oil and grape seed extract added to Lyoner-type sausages improved their odor and color scores, extended their shelf life during refrigerated storage and inhibit the growth of *Clostridium perfringens* in artificially contaminated samples (Aminzare et al., 2018).

Essential oils could be applied as natural antimicrobial and antioxidant agents for fish and other seafood to protect them from microbial spoilage and lipid oxidation and prolong the shelf life (Hassoun and Coban, 2017). To increase effectiveness of treatment, combinations of different essential oils could be used. However, it is necessary to study possible cytotoxicity and toxicity of used essential oils.

It was proposed to use edible microcapsules containing essential oils, especially the starch microcapsules, for prolongation of the shelf life of food instead of chemical preservatives (Ju et al., 2020). These microcapsules are environmentally friendly; ensure slow release of essential oil, and protect food products from the flavor influence.

Microencapsulated essential oil from *Perilla frutescens* L. Britt had good antibacterial activity and was recommended to be used for strawberry preservation and prolongation of the shelf life (Li et al., 2018).

Trend 3. Extracts from plant materials for replacement of synthetic antioxidants

Extracts from fruits, vegetables, spices, and herbs usually contain phenolic substances which ensure their strong antioxidizing activity. So, these natural products could replace synthetic antioxidants in preparation of food (Aminzare et al., 2019).

Extracts of plant Roselle (*Hibiscus sabdariffa* L.), used in traditional folk medicine in many countries, are rich in polyphenols such as polysaccharides, anthocyanins, and organic acids (Riaz and Chopra, 2018). Compounds from these extracts have antioxidant and antibacterial properties and can be used as natural additives (Marquez-Rodríguez et al., 2020). A phenolic extract obtained from hibiscus calyces possessed antimicrobial activity against such foodborne pathogens as *Listeria monocytogenes*, *Salmonella enterica*, *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus cereus* and being using for meat products preparation showed preservation effect. Spraying of ethanolic or phenolic extracts from hibiscus on beef steaks resulted in prolongation of the meat's shelf life (Marquez-Rodríguez et al., 2020). Generally, there are a lot of studies which propose using extracts from different fruits and vegetables as natural antioxidants for meat products. Some examples are shown in Table 1.

Table 1

Use of extracts from plant materials as natural antioxidants in meat products

Extracts from	Meat product	References
Acerola fruit	Beef patties	Realini et al., 2015
Guarana seed or Pitanga leaf	Lamb burgers	de Carvalho et al., 2019
Ginkgo leaves	Meat balls	Kobus-Cisowska et al., 2014
Hibiscus calyces	Beef steaks	Marquez-Rodríguez et al., 2020
Hyssop	Pork meat	Fernandez-Lopez et al., 2003
Lotus seed epicarp	Chinese sausage	Qi and Zhou, 2012
Mugwort and Rosemary	Pork patties	Hwang et al., 2016
Murraya koenigii berries	Meat batter	Kumar and Kumar, 2020
Red pitaya	Pork patties	Bellucci et al., 2021
Rosemary	Pork meat	Fernandez-Lopez et al., 2003
Ulam raja leaves	Beef patties	Reihani et al., 2014
Pitangueira leaves	Pork sausage	Luciano et al., 2021

The addition of extract from acerola (*Malpighia emarginata*) extended the shelf life of beef patties by improving their lipid stability (Realini et al., 2015). Extracts from ulam raja leaves (*Cosmos caudatus*) and green tea extract incorporated in beef patties demonstrated a strong lipid oxidation inhibitory effect and an improvement in cooking yield and textural properties (Realini et al., 2014). The incorporation of mugwort (*Artemisia vulgaris*) extract, rosemary (*Rosmarinus officinalis*) extract and ascorbic acid added in quantity 0.05% each

delayed oxidative deterioration and maintained quality of pork patties during their refrigerated storage (Hwang et al., 2016). Extract from less conventional plants, such as Pitangueira (*Eugenia uniflora*), was proposed to be added in fresh pork sausage to extend their shelf-life (Luciano et al., 2021). Extracts from rosemary or hyssop inhibited lipid oxidation, degradation of heme pigments, and slowed down metmyoglobin formation during cooking and storage (Fernandez-Lopez et al., 2003). Lotus (*Nelumbo nucifera* Gaertn) seed epicarp, the main by-product of lotus seed processing, is rich in polyphenols. Extracts from lotus seed epicarp being used for supplementation of pork homogenate which represented Chinese Cantonese sausage resulted in retarding of lipid oxidation (Qi and Zhou, 2012). Extract from Ginkgo (*Ginkgo biloba*) leaves added in pork meatballs inhibited lipid and cholesterol oxidation processes during 21 days of products refrigerated storage (Kobus-Cisowska et al., 2014). The addition of red pitaya extract to pork patties improved consumer acceptance of these meat products due to improving colour and extended the shelf life of parties during storage at 2°C due to retarding the oxidative processes (Bellucci et al., 2021). The addition of encapsulation *Murraya koenigii* berries extract ensured higher oxidative stability of meat batter (Kumar and Kumar, 2020). Incorporation of guarana seed or pitanga leaf extracts delayed discoloration and ensured oxidative stability of the lamb patties during their refrigerated storage, meanwhile sensorial properties were not changed (de Carvalho et al., 2019).

It is known that berries contain a lot of phenolic compounds, especially anthocyanin. Extracts of such berries as bearberry (*Arctostaphylos* sp.), blueberry (*Vaccinium* sp.), blackberry (*Rubus* sp.), cloudberry (*Rubus chamaemorus*), cranberry (*Vaccinium* sp.), blackcurrant (*Ribes nigrum*), strawberry (*Fragaria ananassa*), and grape berries (*Vitis* sp.), contained antioxidant polyphenols, so, they were recommended to be used for stabilizing meat products instead of synthetic antioxidants (Lorenzo et al., 2018). Extract from cloudberry showed strong antioxidant activity due to presence of flavonoids and was recommended to be added to pork patties to prevent lipid oxidation in the cooked product (Rey et al., 2005).

Extract from herbs could be used for stabilization of oil that replaces fat in meat products. Chia oil was enriched with rosemary obtained with ultrasound-assisted extraction to ensure oil oxidative stability. This mixture was microencapsulated and used to replace 50% fat in burgers (Heck et al., 2018). The similar effect was observed when guarana seed and pitanga leaf extracts were added as natural antioxidants to lamp patties prepared with replacement of fat by chia oil emulsion (de Carvalho et al., 2019). It was shown that addition of mentioned plant extracts delayed discoloration of the lamb patties during storage at 2°C, as well as lipid and protein oxidation, without changes of their sensorial properties. Replacement of 20% pork back with dietary fiber extracted from makgeolli lees did not decrease the quality of frankfurters with 30% fat (Choi et al., 2014). Jaboticaba (*Myrciaria jaboticaba* (Vell.) Berg) is a Brazilian grape-like fruit. The addition of up to 0.5% of jaboticaba peel extract to bologna-type sausages improved their oxidation stability during storage due to extract antioxidant activity without affection of sensory quality (de Almeida et al., 2015).

Use of thuja (*Thuja occidentalis*) cones or peach (*Prunus armeniaca*) seeds extracts with the content of total phenolic compounds 0.8 and 0.2% by dry weight, respectively, were added in quantity 50 mL of extract to 1 kg of minced meat in raw chicken ground meat as antioxidants (Yogesh and Ali, 2014). Addition of these extracts inhibited lipid oxidation during chicken ground meat storage at 4°C, increased water holding capacity and decreased cooking loss. However, authors noticed that *Prunus* family kernels and thuja cones contain compounds which could have toxic effects being consumed more, so further studies were

needed to estimate the possibility of using these fruit extracts in meat preparation. Cinnamon (*Cinnamomum Zeylanicum*) essential oil contains phenolic and polyphenolic compounds and could be used in low concentrations (0.02% and 0.04% v/w) in preparation of Lyoner- type sausage to inhibit lipid oxidation and increase sausages chemical stability (Aminzare et al., 2015).

Natural polyphenols extracted from different plants have the potential to be used as antioxidant and antimicrobial agents instead of synthetic additives to preserve fish and fish product quality (Maqsood et al., 2013). There are also some researches concerned about their use as functional ingredients in meat and fish processing (Gokoglu, 2019; Patel, 2015).

Natural antioxidants can be added to edible oils to enhance their stability. For example, addition of essential oils from cinnamon or clove to hazelnut or poppy oils successfully prevented lipid oxidation and were recommended to be used instead of synthetic antioxidant butylated hydroxyanisole (Ozcan and Arslan, 2011).

Plant extracts could be used in the dairy products. It was shown that the extracts from such spices and herbs as cinnamon, cloves, garden cress, oregano and lemon grass demonstrated antibacterial activity against foodborne pathogens including *Listeria monocytogenes*, *Salmonella typhimurium*, *Staphylococcus aureus*, and *Escherichia coli*. Being incorporated in cheeses they also enhanced taste, odor, color and total quality of the product (Tayel et al., 2015). Effectiveness of five spice and herb extracts used against development of three foodborne pathogens in cheese at room temperature 23°C was demonstrated (Shan et al., 2011). The decrease of pathogen numbers and the inhibition of lipid oxidation were observed in cheese treated with these extracts.

Plant extract can be incorporated in dairy products replacing synthetic additives to improve their antioxidant activity. Thus, cottage cheese added with aqueous extracts of fennel (*Foeniculum vulgare* Mill) or chamomile (*Matricaria recutita* L.) microencapsulated in alginate showed higher antioxidant activity after the 7th day of storage in comparison with control prepared without plant extracts (Caleja et al., 2016). Combination of essential oils and plant extracts is an attractive alternative for synthetic preservatives in cheese production to ensure microbiological safety of the products (Gouvea et al., 2017). However, the influence of their incorporation on activity of lactic bacteria and the sensory characteristics of products should be studied as well as studies concerning more effective combinations of different essential oils and plant extracts.

Cinnamon leaf and bark essential oils added in quantity of 0.5% in strawberry shakes showed strong antimicrobial activity against *Salmonella typhimurium* and *Listeria monocytogenes* and completely inhibited both bacteria after 8 days storage at 4 °C (Brnawi et al., 2018).

Natural antioxidants were also proposed to be used in bakery products. For example, the incorporation of fennel and chamomile aqueous extracts rich in phenolic compounds in biscuits ensured similar antioxidant activity as a synthetic antioxidant, the butylated hydroxyanisole, widely used in food production (Caleja et al., 2017).

Despite evident beneficial effects on food stability and its protection from microbial spoilage and oxidation, more studies should be conducted to prove safety of essential oils or plant's extracts in food production and evaluate possible side effects (Lourenço et al., 2019; Ribeiro-Santos et al., 2017). New antioxidants to be used in food production should be approved by the European Food Safety Authority (EFSA) or by the United States Food and Drug Administration. A new food additive must be safety evaluated by (1) its chemistry and specifications; (2) existing authorizations and evaluations (data of previous risk assessments); (3) proposed uses and exposure assessment, and (4) toxicological studies (ANS, 2012).

Trend 4. Application of seaweeds in food nutrition

Edible seaweeds (macroalgae) are presently a subject of many investigations. Macroalgae have been a part of local nutrition in Asian East and Southeast countries from ancient times, and the health benefit of seaweed and seaweed extract is shown in different studies (Brownlee et al., 2012; Shannon and Abu-Ghannam, 2019). Seaweeds or seaweeds extracts were proposed to be used to increase health value and shelf life of different food products as well as for preparation of low-fat products with decreased content of calories and saturated fatty acids and improve overall quality of foods (Roohinejad et al., 2017). Edible seaweeds are considered to be a good source of dietary fibers, peptides, phlorotannins, essential amino acids, antioxidants, vitamins, unsaturated fatty acids, carotenoids and abundant minerals that can be incorporated in meat, fish, bakery and others food products as a source of nutrient as well as a source of compounds needed to be consumed by people suffering from a wide spectrum of disorders or diseases (Lordan et al., 2011; Fitzgerald et al., 2014; Cardo et al., 2014; 2015).

There is a lot of research about using macroalgae, or extracts from them to create new products which could be used by the population suffering from different cardiovascular diseases (Cardoso et al., 2015). Mainly meat-based products with addition of seaweeds were proposed and studied as functional foods for populations with cardiovascular-health problems. The main aim of seaweed incorporation in the meat products is to improve the composition of fatty acids and to reduce the content of cholesterol, salt and fat. To improve fatty acid content of such meat products as patties, frankfurters and steaks seaweeds wakame *Undaria pinnatifida*, nori *Porphyra umbilicalis*, and sea spaghetti *Himanthalia elongata* were added as a source of bioactive substances with simultaneous reduction of content of sodium and fat (5% of each seaweed to pork meat) (Cofrades et al., 2017). These meat products were tested on male rats to study their health effects. The authors indicate that every kind of algae has its own effect based on its composition, and should be subject of individual study.

Research done in Korea with volunteers showed that addition of sea tangle *Laminaria japonica* to chicken and pork patties had improved postprandial plasma glucose and lipids profiles in borderline-hyperlipidemic adults (Lim et al., 2013).

To reduce sodium content in meat products, addition of selected seaweeds (*Porphyra umbilicalis*, *Palmaria palmate*, *Himanthalia elongata* or *Undaria pinnatifida*) in quantity 1% (w/w) in reformulated frankfurters were conducted to replace salt. The most promising results were obtained when seaweed *H. elongata* was used (Vilar et al., 2020).

Edible seaweeds have been a source of selenium and iodine (Cherry et al., 2019; Circuncisao et al., 2018) which are needed to ensure optimal thyroid function (Schomburg and Kohrle, 2008). Preparation of functional meat products enriched with seaweeds *Cystoseira* or *Fucus* (2% by dry weight to raw stuff) was proposed to supply the population with needed daily quantities of iodine and selenium (Kryzhova et al., 2021).

Bakery products are other subjects to be enriched with microalgae. Seaweeds *Lemna minor* or *Ulva rigida* were studied as additives in bread preparation to extend its shelf-life (Kılinc et al., 2013). A renin-inhibitory protein of edible seaweed *Palmaria palmata* was incorporated in bread at quantity 4% (Fitzgerald et al., 2011). It was shown that the bioactivity was evident after bakery procedure but no significant changes in texture or sensory properties were observed. The addition of seaweed *Ascophyllum nodosum*, 4% per loaf, reduced energy intake at a meal but not nutrient uptake (Hall et al., 2012).

Effect of addition of *Fucus vesiculosus* seaweed powder to wheat flour on dough and bread properties showed that it could be added at maximum of 4% (flour basis) without

deterioration of enriched breads (Arufe et al., 2018). Further increase of quantity of seaweed powder added to dough resulted in significantly increasing of density and crumb firmness and changing of bread crust colour.

For the last few years some beverages prepared with microalgae or extract from them were developed. These beverages were proposed to be used as health drinks. Beverage prepared from macroalgae sea trumpet possessed strong antioxidant properties correlated with the contents of polyphenols (Nagai and Yukimoto, 2003). Beverages prepared from this sea algae had angiotensin I-converting enzyme inhibitory activities: sea trumpet (0.625 mg dry matter/mL), hizikia (7.79 mg dry matter/mL), and wakame (26.4 mg dry matter/mL) and could be used not only as drinks supplying minerals, but also to suppress the hypertensive activity of angiotensin I (Nagai et al., 2016). To prepare a beverage for the prevention of hypertension, seaweed *Hizikia fusiforme* was used as a main part of composition (Kim, 2008).

So, seaweeds could have wide applications in preparation of food products with certain health benefits. However, when seaweed is added to a food product as a source of a certain component it is necessary to estimate possible effects of other substances presented in this seaweed. For example, seaweed *Laminaria* contained too much selenium and iodine to be recommended as additives for meat products in concentrations higher than 1–2% (Kryzhova et al., 2021). The content of seaweed added to products should be higher regulated because health effects could depend on the quantity of seaweed consumed. For example, consumption of parties with cooked rice containing sea tangle powder substituted, 2.5% of meat, by women volunteers improved blood glucose concentration; meanwhile patties substituted with cooked rice containing 25% or 50% sea tangle powder might ameliorate plasma lipid profiles (Oh and Lim, 2011). So, the health benefits of new products should be checked before they could be recommended for the food market. Physico-chemical and sensory quality of food product depends on the quantity of added seaweed. Addition of powder of *Fucus* or *Cystoseira* in quantity 2% to raw stuff in preparation of different meat products did not significantly change their sensory properties (Kryzhova et al., 2021). Characteristics of pork parties with sea tangle powder of *Laminaria japonica*, 1 – 3%, were similar to the control parties (Choi et al., 2012). Meanwhile, a comparison of the quality of the breakfast sausage containing 1, 2, 3, and 4% powder of *Lamina japonica* showed that sausage with 1% had the highest overall acceptability (Kim et al., 2010). The addition of 2 – 8% dried red seaweed *Kappaphycus alvarezii* powder to wheat flour increased the water absorption of the dough and decreased its stickiness properties (Mamat et al., 2014). However, no significant difference in the slickness values of the dough added with different quantities of seaweed was observed. The firmness of the bread increased over the period of storage and positively correlated with the percentage of seaweed powder added to flour. The quality of produced bread was affected by the amount of added seaweed (Figure 1). The addition of seaweed decreased the bread density, the volume of bread and increased the yellowness of the bread crumb obtained.

Figure 1. Bread produced with seaweed powder, %:
0 (F1), 2% (F2), 4% (F3), 6% (F4), 8% (F5).
(Adapted from Mamat et al., 2014).

Trend 5. Plant seeds as additives to food products

Seeds of different plants have specific chemical compositions and in recent years a lot of researches studying the possibility of their usage for preparation of functional food products were published. Chia seed has been in the focus of many studies. Chia (*Salvia hispanica* L.) originally was grown in Mexico and Guatemala and the nutritional properties and health-promoting properties of chia seeds are known, especially, due to oil content (between 30% and 33%) with high percentage of unsaturated fatty acid (around 80% of total acid value) and presence of omega-3 α -linolenic acid and other polyunsaturated fatty acids. Chia seed is also a source of dietary fiber (up to 38%), minerals (4–5%), and protein (15–25%) (Kulczynski et al., 2019; da Silva et al., 2017). The seeds are characterized also by high contents of polyphenols and antioxidants (Hrncic et al., 2020). For its nutrient and health values chia seed was announced as plant material which is “The new golden seed for the 21st Century” (Orona-Tamayo et al., 2017).

The use of chia seeds to enhance the quality of food products has been studied intensively. The addition of chia seeds to beef burgers doubled or tripled the content of polyunsaturated fatty acids, increased the content of polyphenols and antioxidant activity (Antonini et al., 2020). Hedonistic tests conducted for different age groups of population showed acceptability of this food product and indicated its potential application as a functional burger.

Chia seeds were added to different bakery products to improve their nutritional value. It was shown that addition of chia seed mucilage in bread and cakes for replacement up to 50% of fat did not affect significantly technological and organoleptic characteristics of healthier bakery products (Fernandes et al., 2017).

The addition of chia flour to the biscuits improved not only the nutritional value of the product, but also increased the antioxidant capacity, content of phenolic compounds, protein,

fiber and polyunsaturated fatty acids; however, contamination process was increased, so the shelf life of the product was decreased (Mesias et al., 2016).

It was shown that reduction of the amount of hydrogenated vegetable fat with chia seeds or chia flour in breads increased the levels of fibers and polyunsaturated fatty acids, mainly omega-3, but affected the technological quality of the loaves decreasing the specific volume and the total score values. However, both types of bread obtained a high level of acceptability by consumers, meanwhile bread with the addition of chia flour had a higher index of purchase intent than the bread with chia seeds (Coelho et al., 2015).

It was proposed to use different seeds to be incorporated in the different bakery products. Pumpkin seeds could serve as a source of proteins with high content of tryptophan, carotenoids, protein, minerals, including zinc, iron, magnesium and manganese, fiber and omega 3 and omega 6 fatty acids. Pumpkin seed products were added to wheat flour to produce blends with protein levels of 15, 17, 19 and 21% for loaves of breads production (El-Soukkary, 2001); it was recommended the addition of pumpkin seeds powder to wheat flour up to 15% to improve nutrition value and sensory quality of cookies (Alshehry, 2020); 50% replacement of wheat flour with pumpkins seed flour was proposed in preparation of cupcakes (Batista et al., 2018). Pumpkin seeds flour was recommended to be added in gravy to increase its nutrition and health value (Sharma and Sarla, 2017).

Flaxseed (*Linum usitatissimum*, L.) has high contents of protein and fiber and low contents of carbohydrate and fat, contains such compounds as phenolic acids, lignans and flavonoids with antioxidant characteristics, minerals especially Ca, K, P and Mg (Khaled et al., 2019). Flaxseeds have potential health benefits including reduction of blood cholesterol levels and the risk of cardiovascular diseases. Sensory evaluation of bread and cakes showed that partial replacement of wheat flour especially in the range of 5 to 10 per cent with flaxseed meal could be conducted without significant changes of organoleptic properties but with enhancement of fiber and protein contents (Khaled et al., 2019).

Preparation of cookies with partial replacement of the wheat flour with roasted or ground flaxseed showed that cookies with 15% level of substitution and below had acceptable evolution properties (Rajiv et al., 2012). Incorporation of red mombin (*Spondias purpurea* L.) seed flour into the chocolate brownies produced using wheat flour increased dietary fiber and ash contents, physical characteristics, and antioxidant activity allowing longer preservation of the product. It was shown that red mombin seed flour could completely replace wheat flour in chocolate brownies (de Abreu et al., 2021). Microencapsulated garden cress seed oil in whey protein concentrate with oil/protein ratio of 0.4 was used in biscuits preparation to replace flour and fat (Umesha et al., 2015). It was shown that annatto (*Bixa Orellana* L.) seeds powder served as a source of antioxidants to retard lipid and protein oxidation in pork patties during their storage at 4°C and displayed also antimicrobial activity (Cuong and Chin, 2016).

Trend 6. By-products of plant processing for food preparation

Many by-products of plant processing were proposed to be used as antioxidants in preparation of meat products (Aminzare et al., 2019). Half of the nitrite in the pork luncheon roll was replaced with 1.5% of tomato (*Solanum lycopersicum*) pulp powder. Rolls with reducing content of nitrite had higher acceptability. However, the addition of bigger amount of tomato pulp powder (3%) affects the colour and texture of the rolls (Hayes et al., 2013). Extracts from tomato pomace used for spreading on lamb longissimus thoracis surface showed antioxidant activity and improved shelf-life of atmosphere-packaged meat (Andres

et al., 2017). Quinoa paste was used at quantity 5% for partially replacing fat in pork liver pate (Pellegrini et al., 2018). The addition of quinoa paste to pork liver pate retarded the lipid oxidation, increased emulsion stability, so stability of the product was increased. At the same time, the samples with quinoa pasta had higher fiber content and reduced content of fat, so the healthiness of the product was improved. The most acceptable sample was the pâté containing red quinoa at 5%.

Addition of different plant materials to dough, mainly for replacement of animal fat to improve health properties of food products, was studied. However, application of hemicellulose- containing substances was also tried to be used for replacement of sugar or flour in bakeries. Ginger powder was proposed to be added (1% and 2%) to rabbit burgers (Mancini et al., 2017). The results showed that this addition increased the content of polyunsaturated fatty acids omega-3 and omega-6 as well as antioxidant capacity of rabbit burgers while lipid peroxidation values were decreased. By-products, such pomaces or puree, from the fruit juice industry are characterized by high content of bioactive components and fiber. Addition of green banana puree in pound cakes for replacement of traditionally used butter were studied (de Souza et al., 2018). It was shown that replacing fat at 25% resulted in reduction of 20% and 40% of sugar in green banana puree low-fat cakes meanwhile sensory characteristics did not change significantly. It was shown that the sponge cakes cooked with black currant and aronia pomace for replacement of fat (30% substitution) were well accepted by consumers, meanwhile partial replacement of sugar or flour decreased the quality of sponges (Quiles et al., 2018). Replacement of up to 50% of fat (butter) by avocado puree in muffins resulted in decrease of caloric value of low-fat muffins; meanwhile their organoleptic properties were acceptable (Othman et al., 2018). Okra gum was recommended to be used for replacement of fat (100% substitution) in chocolate bar cookies (Romanchik-Cerpovicz et al., 2002).

Trend 7. Replacement of gluten in bakery products

In recent years, a lot of research was conducted to find the ways for replacement of gluten proteins in bakery products. Gluten proteins, mainly gliadins and glutenins, represent about 80% of the wheat flour protein and ensure the elastic and extensible properties of dough. However, it has been considered as a wheat grain allergen and about 1% of the world population is sensitive to gluten (Battais et al., 2008; Wang et al., 2017). So, there are a lot of propositions of the replacement of wheat flour with different gluten-free cereal flours to produce gluten-free bakery products (Peris et al., 2019). Among gluten-free cereal flours used for substitution of wheat flour there are rice flour (Bourekoua et al., 2016; Sciarini et al., 2010) corn flour (Bourekoua et al., 2016); sorghum flour (Marston et al., 2016; Rao et al., 2016), and combinations of mentioned above flours, for example, rice and soybean flours in ratio of 70 to 30 (de la Luz Guerrero-Elizarraraz, 2017), rice, corn and soy flours (Sciarini et al., 2010) and others.

There are also a lot of researches studying possibility or the replacement of wheat flour by flour of pseudo-cereals such as buckwheat (*Fagopyrum esculentum* and *Fagopyrum tartaricum*) (Jan et al., 2015; Sakac et al., 2015), legume flours (Cheng et al., 2016; de la Hera et al., 2012; Pasqualone et al., 2019a), quinoa (*Chenopodium quinoa*) (Watanabe et al., 2014), amaranth (*Amaranthus* sp.) (Chauhan et al., 2016) and their mixture (Buresova et al., 2017).

It is known that gluten is responsible for flour technological characteristics to make high quality bakery products. However, it was shown that combination of some flours with certain

properties allowed to obtain gluten-free bread with good characteristics. Thus, gluten-free breads prepared with different combinations of rice, corn and soy flours differed significantly by their quality. It was established that bread made from a mixture of rice, corn and soy flours, taken in ratio of 40:40:20, had the best qualities characteristics such as high specific volume, good crumb appearance and soft texture (Sciarini et al., 2010) (Figure 2).

Figure 2. Images of gluten free bread slices: rice (a), rice/soy 90:10 (b), rice/corn 50:50 (c), corn/soy 80:20 (d), rice/corn/soy 45:45:10 (e), rice/corn/soy 40:40:20 (f) ((Sciarini et al., 2010).

Addition of quinoa (*Chenopodium quinoa*) flour to the cookies to substitute for 7.5% or 15% of wheat flour increased their antioxidant capacity, content of lysine and decreased the peroxide value (Watanabe et al., 2014). In spite of that, the addition of 15% of quinoa flour affected flavor and it was suggested that they were acceptable to the panelists. In another

research, the cookies added with amaranth flour up to 60% showed good acceptability (Chauhan et al., 2016).

The mixture of gluten free flours of amaranth, buckwheat, chickpea, corn, millet and quinoa was blended with rice flour to compare their effect on technological parameters of bread production (Buresova et al., 2017). Addition of buckwheat flour (30 g/100 g; 50 g/100 g of rice flour) improved bread quality, meanwhile addition of amaranth, chickpea and quinoa flours affected the aroma and taste of breads, and addition of millet and corn flour deteriorated dough and bread quality.

Recently, a lot of research was done connected with usage of acorn flour in bread preparation. Acorn flour is rich in bioactive compounds, antioxidants and can be used as a gluten free material for bakery (Martins et al., 2020; Pasqualone et al., 2019b). Acorn flour added in the quantity of 23% and 35% of the flour mixture which consisted of buckwheat and rice flours showed good technological properties and its usage could improve bread nutritional and sensory characteristics (Martins et al., 2020).

Trend 8. Seed oil in food production

Application of a mix of grape seed oil (0%, 5%, 10% and 15%) and 2% rice bran fiber was proposed for partially substituting the pork fat content in meat batter. The samples with increasing content of grape seed oil had not only reduced content of the animal fat, but were characterized with lower loss during cooking emulsion stability, and apparent viscosity (Choi et al., 2010).

Grape seed oil was also proposed to be used in preparation of meat emulsion. Grape seed oil emulsified in combination with gelatin and alginate was used for partial replacement of pork fat. This replacement improved the quality of meat emulsion and its health value (Kim et al., 2020). Grape seed oil demonstrated higher antioxidant activity than sunflower oil and olive oil. The addition of grape seed oil for 40% fat replacement in pork patties reduced the formation of heterocyclic amines during cooking without change of eating quality.

Trend 9. Dietary fibers in food production

Dietary fiber is the part of plant food that cannot be absorbed by humans and is resistant to enzymatic digestion in the human gastrointestinal tract (Yang et al., 2017). By their chemical structure dietary fibers with the exception of lignin are polysaccharides such as cellulose, hemicellulose, pectin, gums, and mucilage. All dietary fibers are divided in two groups: soluble (cellulose, hemicellulose and lignin) and dissolves in water to form gels (pectin, gums, and mucilage). The numerous studies were conducted to show positive influence of fiber intake and health benefit, mainly by the reduction of blood cholesterol, as well as improving of colonic function, and regulation of blood glucose (Dhingra et al., 2012).

Recommended daily intake of dietary fibre for adults in most countries is between 25 and 35 g (25–32 g/d for women and 30–35 g/d for men) and less for children and older adults (Stephen et al., 2017). Dietary fiber is recommended to be used in preparation of various functional foods like meat products, bakery, drinks, and beverages.

The addition of dietary fiber to meat products was proposed to increase their nutritional and healthy value as well as increase their acceptability and cooking yield (Talukder, 2015). A dietary fiber containing material recovered from the olive mill wastewater was proposed

to be added to meatball to improve their cooking properties and reduce fat content (Galanakis et al., 2010). Sausage is a very popular meat product but the content of fat in it is too high. Partial substitution of fat in sausages with dietary fiber is recommended (Ham et al., 2016; Souza et al., 2019; Yang et al., 2010). Addition of hydrated oatmeal in quantity 10% for partial replacement of fat in sausages resulted in improving of technological parameters such as cooking yield and textural properties and an increasing of low-fat sausages acceptability (Yang et al., 2010). Low-fat beef sausages were prepared with addition of water to replace fat and pineapple fibre was added in quantity of 1% to bind additional water in sausage formulations. (Henning et al., 2016). The textural parameters of low-fat sausages were lower than that of the control, however, addition of pineapple fiber in combination with water is considered as a way to reduce lipid content in sausages, increase the dietary fibre component and improve the health value of product (Henning et al., 2016).

The by-product from the production of red wine from *Vitis vinifera* grapes in the form of flour with a high content of dietary fiber (40%) was used to replace 1, 2 and 3% of bacon in salami preparation (Mendes et al., 2014). This addition resulted in a significant increase in the nutritional properties of the produced salami. Some studies are referred to usage of dietary fibre in preparation of meat emulsions to improve their quality. *Makgeolli* lees, by-product of a production of traditional Korean rice and cereal wine, added as a source of dietary fiber to chicken meat emulsion system in quantity of 2%, improved its stability and viscosity and decreased cooking loss (Choi et al., 2010a).

The addition of dietary fiber to bakery products is widely used to increase their nutritional value, improve their acceptability and extend the shelf-life. The addition of soluble fiber, which was partially hydrolyzed guar gum, 3.4 g, and water, 36 mL, in 100 g flour for noodles preparation had a significant positive effect on textual properties and increased the soluble fiber content to 3.6% as compared to 1.1% in control noodles (Mudgil et al., 2016).

Banana peel is a waste which is produced in a huge quantity as a by-product of the food processing industry. Meanwhile, it is a rich source of dietary fibre (43 – 50%), polyunsaturated fatty (linoleic α -linolenic) acids and micronutrients (Mohapatra et al., 2016). Banana peel powder was proposed to be added to chapati dough up to 20% (Kurahde et al., 2016). It was shown that addition of banana peel powder resulted in increase of dough stickiness and improved pliability. The substitution of wheat flour with 30% matured green banana flour increased total dietary fibre contents, content of minerals as well as antioxidant activity of noodles meanwhile the quality of noodle with banana flour was comparable to the control (Choo and Aziz, 2010). Stabilized rice bran flour with high content of dietary fiber (26%) was added at level of 5% to enrich the pizza dough (De Delahaye et al., 2005). The sensorial evolution showed acceptability of enriched pizza dough and ensured its stability during 60 days at -18°C .

Incorporation of food grade orange fiber extracted from orange juice by-product, consisted from peels and seeds, was tested as a fat-replacer at different percentages (30, 50, and 70%) in brioches, bakery confectionery products (Caggia et al., 2021). It was shown that brioches with 50% fat substitution had lower fat content, increased content of dietary fiber and improved technological properties.

New coffee by-products, silverskin extract, have been proposed to be used as a source of dietary fibre and bioactive compounds in preparation of developed novel food products (Figure 3) (Iriondo-DeHond et al., 2020).

Figure 3. Products with coffee silverskin extract:

(A) beverages from Arabica and Robusta;

(B) wheat bread slice;

(C) gluten-free bread;

(D) biscuits

(Iriondo-DeHond et al., 2020).

There are some studies proposed additions of dietary fiber in dairy products, mainly in yogurts. Among the sources of fiber proposed to be added in yogurts there were oat fiber, wheat bran, pineapple and pina colada, fibers from apple, wheat, bamboo, asparagus, guar gum, orange fiber and date fibre (Hashim et al., 2009). It was shown that addition of fiber in yogurt may increase its health value, but can affect yogurt's technological characteristics and acceptability.

Trend 10. Novel edible coatings materials of plant origins

New trend in food production is an application of edible coating of different food product (fruits, vegetables, meat, fish, bakery, and snacks) to protect their quality, create a barrier against moisture lost and gas diffusion, prevent the loss of natural volatile flavour compounds and color components, delay enzymatic and microbial spoilage and extent shelf life (Sapper and Chiralt, 2018). Edible coating materials could be directly applied by spraying or dipping method over the food product to obtain a thin protective layer, but the preferred technique for edible coating is dipping. Materials for development of edible coating include polysaccharides such as starch, alginate, cellulose, chitosan, pectin, edible biopolymers pullulan and carrageenan, and plants gums; peptides such as gelatin, collagen, gluten, casein, and lipid-based materials, mainly different waxes (Suhag et al., 2020). Natural antioxidant and antimicrobial agents have also been incorporated in the edible film to increase the protection properties of food products and extend their shelf life.

Some examples of edible coating applications are shown below. Coating with 1% chitosan helped to maintain strawberries quality during storage (Yan et al., 2019). Arabic gum and almond gum were proposed to be used as novel edible materials for coating vegetables and fruits. The ripening process of semi-matured green tomatoes treated with aqueous solution of gum arabic, 1.5%, was delayed during their storage at 32°C and 35- 42% relative humidity for 28 days without changes in postharvest quality (Krishnadev, 2017). Coating of sweet cherries with 10% almond gum or arabic gum delayed their ripening during their storage at 2°C and 90–95% relative humidity for 15 days and extended the shelf life (Mahfoudhi and Hamdi, 2015). Coatings with the guar gum, 0.15% (m/v), added with calcium chloride, 0.1% (m/v), glycerol, 0.1% (m/v), and ginseng extract, 1% (m/v), helped

to maintain the quality of sweet cherry and extend sweet cherries' shelf life during storage at 20 °C and 70–75% relative humidity for about 8 days (Dong and Wang, 2018).

Edible films can be used as an alternative for prolongation of the shelf life of fish. Coating with gelatin-chitosan film incorporated with 4% of oregano essential oil was proposed for fish preservation (Wu et al., 2014). Biodegradable chitosan, 2% (wt./vol.), coating incorporated with black pepper essential oil, 1.5% (wt./vol.) was used for common carp fillet coating to extend its shelf life at refrigerated storage at 4°C (Moosavi-Nasab et al., 2016). Rosemary essential and extract oil, 2000 ppm and 200 ppm by total phenol basis, respectively, were entrapped in carboxyl methyl cellulose to be used as edible coating for smoked eel (Choulitoudi et al., 2017). Application of this coating retarded oxidation processes in eel and showed antimicrobial activity against bacteria *Pseudomonas* spp. and lactic acid bacteria.

It was shown that coating reduced microbial load of the samples, improved fish fillet quality with the increasing of shelf life from 8 to 16 days. However, there is no data according acceptability of this coating fish. An edible gelatin films added with carvacrol, a monoterpenoid phenol presented in essential oils in many spices, was used to wrap of prefried breaded hake medallions (Neira et al., 2019). It was shown that the medallions wrapped in film can be cooked and consumed without removing the packaging and acceptance by the consumer was good.

Application of a new edible coating of pectin containing clove essential oil was proposed for treatment of bream fillets for extension of shelf life during refrigeration improved water holding capacity, color, and texture of the fillets, decreased weight loss, lipid oxidation, number of Gram-negative bacteria, meanwhile lactic acid bacteria were not affected (Nisar et al., 2019).

Dry fermented sausages were coated with chitosan added with essential oil of oregano for protection from lipid oxidation during seven months of storage. It was shown that coating sausages had better odor and flavor at the end of the experiment (Krkic et al., 2013). Biodegradable film contained gelatin and incorporated in it 7.5% microparticles of powder papaya peel as natural antioxidant was used as packaging material for lard. It was shown that this packing material was effective as active barrier with high antioxidant activity and was recommended as environmentally friendly packaging of fat products (de Moraes Crizel et al., 2018).

Coating of potato chips was conducted using almond gum concentration 20 g/L, 75 s frying time at 160 °C frying temperature (Bouaziz et al., 2016). It was shown that coating decreased the oil uptake of potato chips by 34% and improved their sensorial qualities such as color, appearance, crispiness, taste, odor which resulted in chip's better acceptability.

It was strongly recommended to incorporate berries into edible films. Thus, blackberries particles with high content of anthocyanin incorporated in arrowroot starch ensured the presence of bioactive compounds and antioxidant capacity of protective film (Nogueira et al., 2019).

Conclusions

Application of novel natural additives, such as plants with pharmaceutical properties, plant materials with antioxidant activity, essential plants oils, extracts from plant materials seaweeds, seeds products, different gluten-free cereal and pseudo-cereals flours for replacement of gluten in bakery products, dietary fibers, edible coatings materials of plant origins, in preparation of different food products is widely studied in recent 10 years. The

main object of these researches is improving the health value of traditional products, saving or improving their quality and acceptability by consumers as well as an extension of shelf life.

Despite evident beneficial effects, careful examination of new products should be done in every case to establish an optimal dosage of additives, to prove its safety and evaluation of possible side effects on human health.

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