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TRADITIONAL USES AND COMPOSITION OF BEE POLLEN: A REVIEW

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***Abstract*:** Global trend is shifting towards natural healthy food product as consumers are demanding food products that are minimally processed. Bee pollen have been recognized as a natural health supplement due to its excellent nutritional and medicinal properties. It has abundance of proteins, lipids, carotenoids, carbohydrates, vitamins, all the essential amino acids and various secondary metabolites. However, due to differences in botanical and geographical origin, the nutritional properties of bee pollen vary greatly. They are attaining great demand in the market as functional component in different food products. Commercially bee pollen is available in the form of granules, pellets, powders and capsules. There is no recent paper available that emphasizes on recent work of involving application of bee pollen in food products and their processing conditions. The current study thus provides an overview of different food products incorporated with bee pollen as functional component.

***Index-terms*:** Bee pollen, bioactive compounds, drying, food products, health benefits

I. INTRODUCTION

Apicultural products have long been used in phytotherapy and diet for their beneficial effects on the body (Ares et al., 2018). Honey, propolis, royal jelly, bees wax, and bee pollen are some of the products collected from apiculture. Due to their high nutritional value and physiological properties, these products are of great commercial interest, as they provide a valuable source of energy and proteins for human nutrition (Domenici et al., 2015). Because of its high nutritional value, bee pollen has recently gained a lot of popularity as a functional food for human consumption (Nuvoloni et al., 2021). The need to highlight importance of bee pollen in the food and medical sector is of great concern.

Pollen is the microscopic structure found in the angiosperms' anther of stamen, and it is the most important component of the flowering plant (Steven, 2014). It is made up of two layers: intine and exine, which shield the oxidation grain's interior from radiation damage and chemical degradation. Exine is made up of a variety of organic and inorganic compounds, including sporopollenin, a complex polymer that provides pollen with chemical resistance (Salazar-González et al., 2020). Pollen is the primary source of protein and other important nutrients for both social and solitary bees, including fatty acids, sterols, minerals, and vitamins (Ghosh and Jung, 2020). Worker honeybees use a weak electrostatic field produced between the bee body (positively charged) and the flower to attract hundreds to thousands of pollen grains (negatively charged). The pollen grains are agglutinated using the combs and hairs on the bees' hind legs, which are moistened with

salivary secretions and nectar to form a single bee pollen pellet (Thakur and Nanda, 2020a). After that, beekeepers capture it using pollen traps at the hive entrance, where pollen is lost from bees' legs and stored in the trap tray (Salazar-González et al., 2020; Nuvoloni et al., 2021).

Because of its high concentration of carbohydrates, proteins, and lipids, pollen is sometimes referred to as the "only perfectly complete food" and "the best food product on the earth." It is also a rich source of bioflavonoids, all essential amino acids, vitamins A, C, D, E, K, B-complex, (Fig 1) including pantothenic acid and niacin, as well as various phytochemicals that improves the body's immune and physiological systems (Kostić et al., 2020, Nuvoloni et al., 2021). The nutrient rich pollen is very hygroscopic as it came in contact with nectar and salivary thus it has a high moisture content. To avoid rapid fermentation and spoilage, which is crucial in order to extend the shelf life (Ares et al., 2014) the bee pollen must be consumed either fresh or quickly dried to retain the nutrients (Thakur and Nanda, 2020). Soil type, plant origin, weather, beekeeper activities, processing and storage all affect the composition of commercial bee pollen (Ares et al., 2018).

Since ancient times, bee pollen has been commonly known as having medicinal and nutritional potential. Previously, women who consumed bee pollen in their diet retained their fitness, appearance, and physical strength (Li et al., 2018). Pollen bioactive metabolites have been extensively researched for anti-inflammatory, antioxidant, antimicrobial, and anti-tumor properties (Mărgăoan et al., 2019). Pollen is also known as a useful method in the treatment of a variety of nonallergic diseases. Essential fatty acids, phospholipids, phytosterols, flavonoids, and phenolic acids are the most common pollen compounds that are thought to have significant pharmacological effect (Li et al., 2018; Antonelli et al., 2019).

Bee pollen is also commercially available as a dietary supplement in the form of granules, pills, capsules, powders, pellets, candy bars, oral liquids, and tonics for human consumption (Li et al., 2018). In Argentina, Brazil, and Switzerland, where standard physicochemical and microbiological quality norms have been established, bee pollen has been recognised by law as a food additive (Thakur and Nanda, 2020a). No specific legislation for pollen is available in the European Union (Nuvoloni et al., 2021). There are a number of literature review papers available that provide a comprehensive overview of pollen nutrients, phytochemicals, and their beneficial effects on human health as well as potential therapeutic properties (Thakur and Nanda, 2020a, Nuvoloni et al., 2021, Ares et al., 2018, Li et al., 2018). With the increased knowledge about functional foods, a variety of pollen-based fermented foods have been produced, including baking, confectionary, juice, and meat preservatives.

The aim of this paper is to provide an overview of bee pollen's recent developments in the food industry over the last five years, with a focus on bee pollen's therapeutic value. Different technologies for drying bee pollen are also discussed, with a summary of safety and regulatory concerns.

II. TRADITIONAL USES OF BEE POLLEN

Pollen from bees has been used for 300 years, and it has been used continuously since then. It has been known for centuries for its medicinal and health-promoting properties. It was part of the ancient population's diet, especially that of the Chinese and Egyptians (Denisow, and Denisow-Pietrzyk 2016). It has been traditionally used as natural food which prevents aging and boosts energy (Klaric et al., 2018). Bee collected pollen began to be used for human nutrition on a larger scale after the Second World War, when pollen traps were developed and became readily available (Campos et al., 2010).

Bee pollen is used in many parts of the world as a favourite preparation in traditional medicine, in apitherapy (Klaric et al., 2018). It has been used as a medication to treat prostatic disorders, wound healing, hay fever prevention, premenstrual syndrome relief, and climacteric symptoms associated with menopause,

among other things (Dias et al., 2016). In Traditional Chinese Medicine, pollen is mainly prescribed as a remedy for malnutrition, alcohol intoxication, skin diseases, and other disorders (Antonelli et al., 2019).

Bee pollen also forms an integral part of biocosmetics. It was used for beauty and skin whitening in ancient China, Proteins, amino acids, carbohydrates, lipids, fatty lipids, phenolic compounds, vitamins, bioelements, and other metabolites found in pollen are used in skin protection for skin whitening, moisturization, free-radical scavenging, anti-inflammatory, and antiaging impact. These effects have provided beneficial support for the development of bee pollen in the field of cosmetics (Xi et al., 2018).

III. NUTRITIONAL COMPOSITION OF BEE POLLEN

Bee pollen's chemical composition varies depending on a number of variables, including botanical sources, bee species, seasonal conditions, plant source, and geographic origins (Gardana et al., 2018; Li et al., 2018). The composition of nutrients can also be altered by processing methods and storage conditions. Bee pollen contains carbohydrates (13–55%), proteins (10–40%), lipids (1–13%), crude fibre (0.3–20%), ash content (2–6%) (Thakur and Nanda, 2020a), polyphenolics (1-2%), Vitamins (0.5-1%) and bioelements (1.5-3%) (Xi et al., 2018). Bee pollen can complement the human diet and provide a substantial daily intake of nutrients due to its excellent nutritional profile. Table 1 summarizes the composition of bee pollen and the average nutritional daily requirement.

Carbohydrates are the most abundant component in dry bee pollen, accounting for 40–85% (W/W). The addition of honey or nectar during pellet formation results in a higher carbohydrate content, which increases carbohydrate content (Thakur and Nanda, 2020a). It is made up of monosaccharides including fructose, which is found in pollen, and glucose, which is also present (Martins et al., 2011). The disaccharides sucrose, turanose, maltose, trehalose, and erlose are present in varying amounts in bee pollen. Bee pollen also contains oligosaccharides and polysaccharides, which help to control a variety of biological functions (Li et al., 2018). Sporopollenin is a polysaccharide found in exine, the pollen grain's outer layer that regulates several biological functions but does not contribute to the pollen's nutritional value (Xu et al., 2009). Gardana et al. (2018) reports that sugar occurs in pollen loads in an amount of 40% ranging from 15-24% fructose, 11–18% glucose and 4–9% sucrose. Other sugars such as arabinose, ribose, isomaltose and melibiose account for about 1% of total sugar.

After carbohydrates, proteins are the second most abundant constituent. In dry bee pollens, it accounts for 14–30 percent (W/W) of the total of 20 essential amino acids (Da Silva et al., 2014). Pollen protein content varies greatly due to different plant sources. It can range from 7% (pine) to 35% (eucalyptus) (date palm). Pollen from Brazil and Argentina may have protein content ranging from 23.5 percent to 27.7 percent and 24.1 percent to 37.3 percent, respectively (Kieliszek et al., 2018). The commercial bee pollen of Attiki Bee Culturing Co. in Greece contained 17.60% protein content (Karabagias et al., 2018). It contains all of the basic amino acids, with proline, glutamic acid, and aspartic acid being the most important. Threonine, Valine, Methionine, Isoleucine, Leucine, Tryptophan, and other amino acids can also be contained (Li et al., 2018). Also 15 g of Spanish pollen is sufficient to satisfy the body's requirements for free amino acids. Pollen from bees is sufficient for human survival, according to some studies (Nogueira et al., 2012). Bee pollen is an outstanding animal feed and human food quality enhancer because of its high protein and amino acid content.

After carbohydrates and proteins, lipids are the third most abundant constituent in bee pollen. They're needed for the creation of royal jelly (Sattler et al., 2015). The lipid content of bee pollen varies greatly depending on the amount of fatty acids, carotenoids, and vitamins present. It can be anywhere from 1% to 13% of the dry pollen weight (Kieliszek et al., 2018, Campos et al., 2008,). Pollen from bees contains a total of 20 fatty acids. Linoleic acid, -linolenic acid, and

arachidonic acid are unsaturated fatty acids, while myristic acid, stearic acid, and palmitic acid are saturated fatty acids (Komosińska-Vassev et al., 2015, Kieliszek et al., 2018). The unsaturated fatty acid (UFA): saturated fatty acid (SFA) of bee pollen ranges from 2.2 to 6.7, indicating that the lipids in bee pollen are of high quality. A higher UFA/SFA ratio indicates lower fat and cholesterol levels, preventing cardiovascular disease; however, if the value is less than 1, the UFA/SFA ratio indicates the deterioration of unsaturated fatty acids over time due to storage and dehydration (Thakur and Nanda, 2018).

Vitamins, especially group B vitamins, are abundant in bee pollen. Among the other group-B vitamins, vitamin B3 with nicotinamide and niacin is the most important component (Arruda et al., 2013). Bee pollen contains around 1.5 mg of vitamin A per 100 g, as well as vitamin E (-tocopherol - 6.2 mg/100 g) and trace amounts of vitamin C (Li et al., 2018). Farag and El-Rayes (2016) referred pollen as “Vitamin bomb” due to presence of almost all vitamins. The botanical sources of bee pollen can be determined by differences in vitamin content between various pollen species. Vitamins are needed for the synthesis of essential cofactors, enzymes, and coenzymes in metabolic reactions (Mellidou et al., 2019).

About 25 different micro and macronutrients are found in bee pollen, including potassium, calcium, copper, zinc, sodium, magnesium, phosphorus, iron, and manganese (Li et al., 2018). Depending on the floral source and country, the sum of each mineral varies. Ca, Cu, K, Mg, Mn, Cr, Fe, Na, P, and Zn were commonly found in bee pollen around the world, while boron (8.2-14 mg/kg), molybdenum (0.1–4.6 mg/kg), and selenium (0.01–4.5 mg/kg) are also found (Thakur and Nanda 2020a). Bee pollen is higher in Zn and Fe than other bee products, and as a food substitute, it could meet 30 percent of an adult human's daily requirements for Fe and 15 percent for Zn (Liolios et al., 2019).

Carotenoids are a diverse group of pigments that range in colour from yellow to red and play an important role in human health (Li et al., 2018). Some of the carotenoids contained in bee pollen include β-carotene, Tocopherol, Lutein, Anteraxanthin, Zeaxanthin, Zeinoxanthin, and -cryptoxanthin (Salazar-González et al., 2020). Corn bee pollen from Thailand and South eastern Brazil includes 1.530 mg/100 g and 1.530 mg/100 g of vitamin A in the form of β-carotene (5.63–19.89 mg/100 g) (Thakur and Nanda 2020a). Mărgăoan et al. (2014) identified several carotenoids from Romanian bee pollen, such as lutein (57.04–476.30 µg/g dry bee pollen), β-cryptoxanthin (1.31–35.43 µg/g dry bee pollen), and β-carotene (trace-18.18 µg/g dry bee pollen).

Polyphenolic compounds, mostly flavonoids and phenolic acids, are abundant in bee pollen. Flavonoids can be found in concentrations ranging from 0.2 to 2.5 percent (mainly flavonols, rutin, catechin, myricetin, leukotrienes, and phenolic acids) (Kieliszek et al., 2018). Quercetin, kaempferol and isorhamnetin are the most common flavonoids found in pollen and the total phenolic content (TPC) can range from 0.50-213 mg GAE/g and total flavonoid content (TFC) 1.00–5.50 mg QE/g. (Karabagias et al., 2018, Kieliszek et al., 2018). Polyphenols in pollen play an important role in pollen germination and encourage pollen tube formation, and they differ in their palynological sources (Li et al., 2018).

IV. CONCLUSION

Bee pollen is a rich source of proteins, carbohydrates, lipids, vitamins, carotenoids, flavonoids, polyphenols and other bioactive component which increases the nutritional value of food in which they are incorporated. Different food processing sectors like bakery, dairy, meat processing, etc. have been using pollen as a source of nutrients to increase the value of food. Further research should be conducted to understand the nutritional diversity of both monofloral and multifloral pollen from different geographical location to for better understanding of their role in food and biomedical sector.

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Table 1 Bee pollen Nutritional composition and Required Daily Intake (RDI)

Nutrients	Amount (mg/100 g)	% RDI for 15 g pollen	Average RDI
Carbohydrates	1.3 - 5.5	1- 46	320
Crude fibre	0.03 – 2.0	0.3 – 18	30
Protein	1.0 – 4.0	5.4 – 22	50
Fat	0.1 – 1.3	0.1 – 4	80
Vitamins			
Ascorbic acid	7 – 56	2 – 15	100
β-Carotene	1 – 20	30 – 600	0.9
Tocopherol	4 – 32	8 – 66	13
Niacin	4 – 11	7 – 20	15
Pyridoxine	0.2 – 0.7	4 – 13	1.4
Thiamine	0.6 – 1.3	15 – 32	1.1
Riboflavin	0.6 – 2	12 – 42	1.3
Pantothenic acid	0.5 – 2	2 – 9	6
Folic acid	0.3 – 1	20 – 67	0.4
Biotin	0.0005 – 0.0007	30 – 42	0.045
Minerals			
Potassium (K)	400 – 2000	5 – 27	2000
Phosphorus (P)	80 – 600	2 – 16	1000
Calcium (Ca)	20 – 300	0.5 – 7	1100
Magnesium (Mg)	20 – 300	2 – 23	350
Zinc (Zn)	3 – 25	10 – 79	8.5
Manganese (Mn)	2 – 11	15 – 85	3.5

Iron (Fe)	1.1 – 1.7	2 – 37	12.5
Copper (Cu)	0.2 – 1.6	4 – 36	1.2

Bee pollen composition is according to Campos et al. (2008) and % Required Daily Intake (RDI) are according to Reports of the Scientific Committee for Food (2010) and Denisow and Denisow-Pietrzyk (2016). RDI is given as g/day for carbohydrates, and as mg/day for vitamins and minerals.

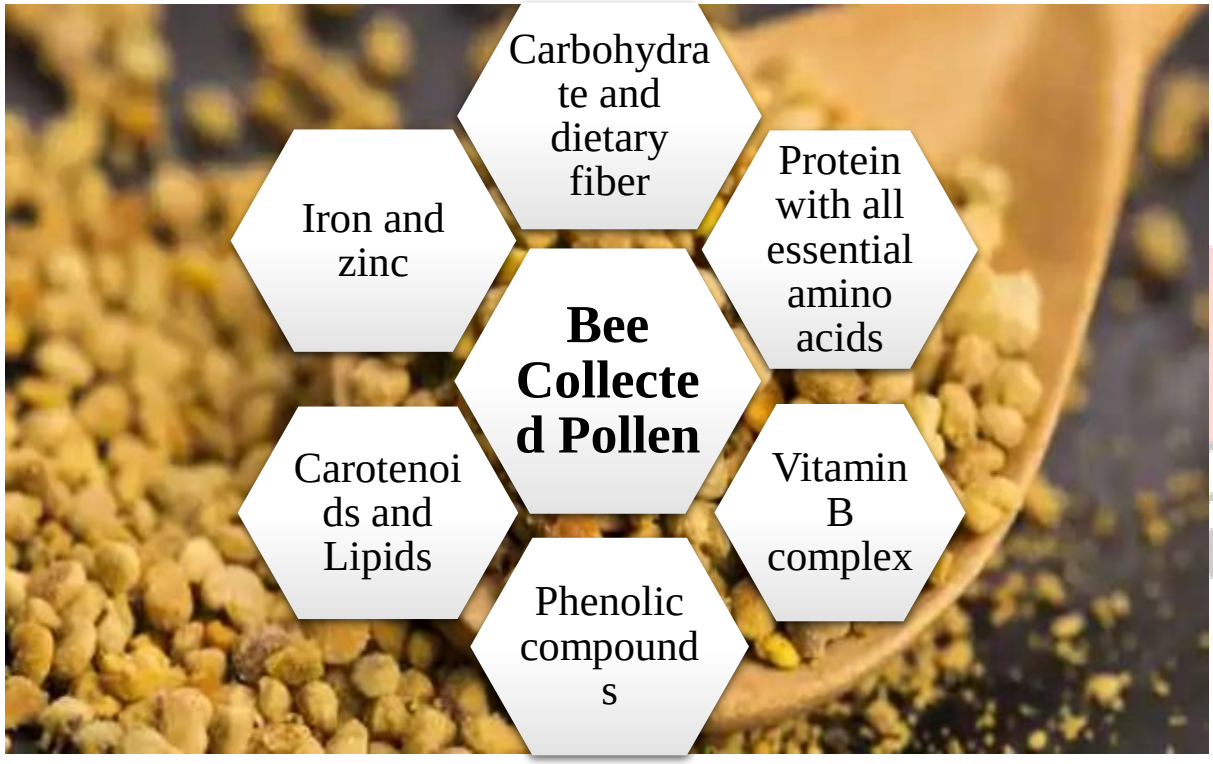

Fig. 1 Important nutritional constituents and functional components of bee pollen