**Royal jelly and pollen as functional foods for human**

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**Abstract**

Bee pollen and RJ is currently used as a functional food or supplementary nutrition in some countries including, China, Chile, Portugal, Australia, South Africa, Brazil and the Sonoran Desert, USA. Royal jelly (RJ) is a bee product secreted from the hypopharyngeal and mandubular glands of young worker honeybees (*Apis mellifera*) and involved in their sexual determination. Royal jelly is one of the most interesting natural products. Pollen has been used as a “perfect health food” for many centuries due to its abundance of nutrimental constituents and bioactive compounds. Pollen is the male gametophyte of flowers. The protein content of pollen is believed to be one of the best indicators for nutritive quality. RJ and pollen contains bioactive compounds with health-promoting properties. They are promoted as a health food with a wide range of nutritional and therapeutic properties.

Functional properties of RJ and pollen include the following: antioxidative activity, Insulin-like action, antitumoral action, neurotrophic action, antibiotic effect, anti-inflammatory action and wound healing effect, hypotensive and blood regulatory actions, anti-aging effect and skin protection, effects on the reproductive system and fertility, fortifying and tonic action and immunomodulatory and anti-alergic activity. Though in Iran there are not insufficient studies in this area.

The purpose of the current research is to determine the main components, physico-chemical properties and healing properties of RJ and pollen and their application as functional and nutraceutical food.

**Keywords**: Royal jelly, pollen, functional food, Human.

1. **Introduction**

Royal jelly (RJ) is a secretion produced by the hypopharyngeal and mandibular glands of worker honeybees *(Apis mellifera)*. This secretion is produced in the worker bees’ stomach by the incomplete digestion of honeydew. Pollen is the male gametophyte of flowers. Bee pollen is plant pollen collected from different sources by the worker honeybee *Apis melliferra* feedingits larvae in the early stages of development. Collected flower pollen is accumulated as corbicular pellets in pollen baskets on the rear legs of the honey bee and it is a mixture of these pellets that comprises bee pollen (Krell, 1996; Campos, 1997; Almeida-Muradian et al., 2007). When visiting flowers, bees touch the stamens and their bodies become covered with pollen dust. The bees use their hind legs to compress the pollen into the pollen baskets. The bees moisten the pollen with mouth secretions which help the pollen to cling together and to the basket hairs (Hodges, 1952; Barth and Luz, 1998; Dutra and Barth, 1997; Krell, 1996; Luz and Barth, 2001). These secretions contains different enzymes, e.g. amylase, catalase etc. A pollen load contains up to 10% nectar, which is necessary for packing. The production of bee pollen might help to increase economic profits and thus help beekeepers to rectify their financial difficulties.

RJ is a part of the diet of honeybee larvae and it plays a major role in caste differentiation (Moritz and Southwick, 1992). For up to 3 days, the larvae are supplied with RJ. Thereafter, only larvae designated to become queens receive RJ, while a mixture of honey, pollen and water is fed to larvae selected to become workers (Drapeau et al., 2006). It is known that the honeybee queen lives for several years compared to a few months for the worker bee (Krell, 1996).

Royal jelly has been known about for ages, but has only been available in the last 50-60 years in quantities large enough for human consumption. China is the largest producer and consumer of RJ.

A functional food is a [food](http://en.wikipedia.org/wiki/Food) given an additional [function](http://en.wiktionary.org/wiki/function) (often one related to general health-promotion) by adding new ingredients or more of existing ingredients; but nutraceutical, a portmanteau the words “nutrition” and “pharmaceutical”, is a food or food product that provides health and medical benefits, including the prevention and treatment of disease.

Royal jelly and pollen, because of their bioactive compounds, are known as functional and Nutraceutical foods; this means that not only they enhance the overall health of the body, but also improve some diseases.

Bee pollen and RJ is currently used as a functional food or supplementary nutrition in some countries including, China, Chile, Portugal, Australia, South Africa, Brazil and the Sonoran Desert, USA.

The present article aims to present a brief review of research studies on physicochemical properties and biological activities of RJ and pollen and their application as functional and Nutraceutical food.

1. **Physicochemical properties**
   1. **Physical Properties**

RJ is a thick and milky substance which is partially soluble in water, with a density of 1.1 g/mL. It have a sharp smell, pungent odour and fruity or somewhat bitter taste and is nutritionally abundant. Its colour is whitish to yellow, the yellow colour increases upon storage. (Haydak, 1970, Isidorov et al., 2009). Pollen grains range in size from 10 to 150 µm and are protected by a chemically resistant outer layer, the exine. Because pollen grains of many plant families are different morphologically, they can be recognized by their distinct shape, size, colour, sculpturing, and number of apertures (Punt et al., 2007). Colour of pollens varies from white to black, mostly yellow, orange or yellow-brown, but many different colours are possible according to the floral sources (Hodges, 1952). Pollen grains are protected by a remarkably complex and robust wall with two layers known as the “intine” and “exine.” The intine, composed of cellulose and a few other polysaccharides, is the innermost of the major layers, underlying the exine and bordering the surface of the cytoplasm (Punt et al., 2007). It is divided into two sublayers: endintine is the inner thicker layer adjacent to the cytoplasm and of cellulosic character; exintine, the outer, thinner layer, stains positively for pectin. Odour of pollens varies according to floral sources and its taste is specific, sweet, sour, bitter, spicy.

* 1. **Chemical composition**

The water content is fairly uniform at greater than 60%, and with an activity (aw) above 0.92. The dry matter of RJ is composed of protein (27-41%, including free amino acids), carbohydrates (approximately 30%), lipids (8-19%), trace elements and some vitamins (Sabatini et al., 2009). RJ has a high acidity (pH 3.4–4.5) (Lercker, 2003).

Monofloral pollen is standard quality pollen with minimal variations, obtained by collecting bee pollen from single botanical taxa; its composition varies with the plant source and geographic origin. Monofloral pollen ensures uniform biochemical and organoleptic characteristics to that of the original plant, while heterofloral pollen exhibits variable properties.

The exine (outer layer of pollen, key and distinguishing feature of pollen grains) is made of sporopollenin, a complex polymer (a β-carotenoid ester) resistant to all but the most extreme oxidizing or reducing agents. Thus, the organic or inorganic matrix in which the pollen grains are trapped can be removed by chemical means without destroying the pollen itself (Cushing, 1967). Sporopollenin is composed of carbon, hydrogen, and oxygen and its stability is illustrated by its being found intact in sedimentary rock some 500 million years old. In contrast to the intine, the sporopollenin exine is acetolysis resistant. Such stability is important in the preparation of microcapsules for food applications since all allergenic proteins, which may be present in the bulk pollen, can be removed readily and cheaply by harsh treatment with strong acid and base. Table 1 shows the main composition RJ and pollen. Table 2 shows the vitamins and minerals of RJ and pollen.

The values of composition obtained by the various authors are fairly in agreement, notwithstanding the high variability displayed for sugars and lipids. It should be kept in mind that RJ is naturally non-homogeneous, moreover the reported findings refer to different number of samples, places and times of production and that different methods of sampling and analysis were used. Analyses of RJ samples of different geographical origins showed that environmental conditions do not significantly influence the main components (Sabatini et al., 2009).

**Table 1: the main composition of fresh and lyophilised RJ and pollen**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Composition | fresh RJ | Lyophilized RJ | fresh Pollen  (Maize) | Pollen  (Mustard) | Pollen (dry weight) |
| water | 50–70%  60-70% | <5% | 45% | 7.26% | 5-6% |
| proteins | 9–18% | 27–41% | 29.7% | 18.2% | 10-40% |
| carbohydrates | 7–18%  7-23 | 22–31% | 22.4% | 56.06% | 13-55% |
| lipids | 3–8% | 15–30%  8-22.5 % | 13.9% | 13.7% | 1-13% |
| mineral | 1.5%  0.8-3 | 2-5% | 2.63% | 2.57% | 2-6% |

**Table 2: Minerals and vitamins RJ and pollen.**

|  |  |  |
| --- | --- | --- |
| **Minerals and vitamins** | **Pollen (mg/kg)** | **RJ (mg/100 g)** |
| Potassium | 4000-20000 | 200- 1000 |
| Magnesium | 200-3000 | 20-100 |
| Phosphorus | 800-6000 |  |
| Iron | 11-170 | 1-11 |
| Zink | 30-250 | 07-8 |
| Manganese | 20-110 |  |
| Copper | 2-16 | 0.33- 1.6 |
| β−Carotene | 10-200 |  |
| B1 (Thiamin) | 6-13 | * 1. 1.7 |
| B2 (Riboflavin) | 6-20 | 0.5- 2.5 |
| B3 (Niacin) | 40-110 | 4.5 19 |
| B5 (Pantothenic acid) | 5-20 | 3.6- 23 |
| B6 (Pyridoxin) | 2-7 | 0.2- 5.5 |
| C (Ascorbic acid) | 70- 560 |  |
| H (Biotin) | 0.5-0.7 | 0.15- 0.55 |
| Folic acid | 3-10 | * 1. 0.06 |
| E (Tocopherol) | 40-320 |  |

1. **Functional properties**

It is supposed that royal jelly makes a balance in the human body. It might be because of a similar balance between its components which are mixed in a suitable proportion.

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| --- | --- | --- | --- |
| **Functional properties** |  | | |
| Antioxidative activity | Royal jelly | protects tissue DNA against the oxidative damage: reducing in levels of oxidative stress marker (8-hydroxy-2-deoxyguanosine) in kidney DNA and serum by feeding RJ to mice | |
| Pollen | Protective effects of pollen have been related to the content of Phenolic constituents (total phenols, phenylpropanoids, flavonols and anthocyanins).  Phytochemicals, such as phenolic compounds are considered beneficial for human health since they decrease the risk of degenerative diseases by decreasing oxidative stress and inhibiting macromolecular oxidation. | |
| Insulin-like action | Royal jelly | RJ is anti-diabetic and prevents insulin resistance.  Insulin-like peptides,chromium, sulphur, vitamins B3 in RJ can reduce blood sugar level.  RJ takes part in the oxidation of glucose to obtain energy and sustains the optimal blood level of sugars. It exhibits Hyperglycaemic action.  There is insulin in RJ very closely resembles the mammals insulin.  RJ reduces alloxan induced diabetes which destructs insulin. | |
| Pollen | A group of steroid hormones such as testosterone, epitestosterone, androstenedione and progesterone have been found in pollens.  Hypoglycemic activity of pollen is mainly attributed to the presence of unsaturated fatty acids, phospholipids, and phytosterols. | |
| Antitumoral action | Royal jelly | 10-hydroxy-2 decenoic acid (10HDA) is responsible for the antitumoral action.  Two major proteins in RJ, apalbumin-1 and apalbumin-2, stimulate macrophages to release TNF-α (tumor necrosis factor).  In patients with breast cancer, RJ stimulated the immuno globuline production by lymphocytes and increased IgM and IgG (the anti-cancer factors).  The RJP30 proteic fraction plays an antitumoral role.  RJ prevents the myelosuppression induced by tumor evolution  (immunostimulating effect).  RJ shows antiestrogenic activity by inhibiting the effect of bisphenol A (an estrogen which stimulates the MCF-7 mammary cancer cells proliferation) | |
| pollen | The ability to reduce platelet clumping and increased fibrinolytic system activity was confirmed in people who take pollen. It shows the antiatherosclerotic effect which protects from heart diseases and brain strokes. | |
| Neurotrophic action | Royal jelly | RJ stimulates and actives central nervous system by Glial Cell-Derived Neurotrophic Factor.  RJ increases the differentiation of brain cells from neural stem cells,  RJ played neurotrophic and neuroprotective roles on the hippocampus of the adult mouse brain.  RJ simplifies the differentiation of all types of brain cells: neurons, oligodendrocytes and astrocytes.  Acetylcholine in RJ is a neurotransmitter in the peripheral and central nervous systems. It is only neuromodulator used in the motor division of the somatic nervous system.  10HDA increases the generation of neurons.  AMP N1-oxid stimulates the formation of different brain cells and the expression of protein specific to mature neurons (neurofilaments-M) and stops the proliferation of PC 12 cells.  RJ Reduces neuronal death and an increase of neurogenesis in Alzheimer's disease and Parkinson's diseases. It improves the spatial memory. | |
| Pollen | Pollen collected by bees contains all nutrients which are necessary for plant growth and development and also targets the entire human body, which is a special boost to the nervous, reproductive and immune. | |
| Antibiotic effect | Royal jelly | Different compositions of RJ show antibiotic effects against microorganisms;  The active substances of RJ are destructed during digestion and it cannot exhibit antibiotic and anti-inflammatory effects. | |
| **compositions** | **Microorganisms** |
| 10-hidroxi-α2-decenoic acid (HDA) | several fungi and bacteria and  (such as *Neurospora sitophila, Micrococcus pyogenes,*  *Escherichia coli*). |
| Royalisin protein | Gram-positive bacteria (*Lactobacilus helveticus,*  *Clostridium, Corynebacterium, Leucnostoc*, *Stafilococcus, Streptococcus*). |
| Jeleines -I, -II, -III | yeast, Gram  positive and negative bacteria |
| Water soluble components (proteins and  Peptides) | Gram positive bacteria and fungi |
| RJ and starch | *Streptococcus aureus* and *E. coli* |
| RJ and honey | *Staphylococcus aureus* and diabetic foot infection |
| Pollen | There are some reports about the antimicrobial activities of pollen.  Bee pollen has recently received an increased attention for its antibacterial and antifungicidal effects. | |
| Anti-inflammatory action and wound healing  effect | Royal jelly | The fatty acids and proteins of RJ and its antimicrobial properties, makes it appropriate for wound healing.  It Improves regeneration of skin in wounds.  MRJP3 of RJ suppresses the secretion of pro-inflammatory cytokines and activates keratinocytes, involved in wound healing.  RJ reduces inflammation by hormone-like effects.  10-hydroxy-2-decenoic acid (10H2DA) and 10-hydroxydecanoic acid (10HDA) increase the collagen production.  RJ shorts the healing period of desquamated skin lesions.  By decreasing exudation, RJ increases wound healing capacity and collagen formation in granulation tissue formation.  RJ causes wound healing by Inhibiting capillary permeability.  RJ heals foot ulcers of diabetic patients. | |
| Pollen | Bee pollen has been successfully used to treat some cases of benign prostatic.  Bee pollen is used in the apitherapeutic treatment as it demonstrates a series of actions such as antiviral, anti-inflammatory and local analgesic and also facilitates the granulation process of the burn wound healing.  Pollen is determined by a high anti-inflammatory activity. Its value is compared to such nonsteroidal antiinflammatory drugs as naproxen, analgin, phenylbutazone, or indomethacin. | |
| Hypotensive and blood regulatory actions | Royal jelly | RJ has Hypo-cholesterolemiant and hepato-protective action and it is efficacy effective in controlling and lowering cholesterol and triglycerides by attaching the phytosterols like biosterol in the intestinal tract, increases HDL levels and number of blood cells, lowers plasma fibrinogen levels and thrombosis, prevents myocarditis.  This effect may be due to the adjustment of squalene epoxidase enzyme (SQLE) and the low density lipoprotein receptors (LDLR) which incorporate cholesterol in the liver.  RJ has Anti-hypertenisive, hypotensive, vasodilatative effects.  RJ increases the oxygen flow to the liver and promoted hepatocytes growth and liver health.  RJ preventes nocotine-1 induced by increasing of cholesterol levels.  RJ improves the quality and number of the red blood cells.  RJ and its peptides reduce high blood pressure due to trans-2-octenoic acid and the hydroxydecanoic acid.  RJ actives against stenocardia and heart infarct | |
| pollen | Clinical studies approved the hypolipidemic activity of bee pollen. It was also successfully used in hyperlipidemia and atherosclerosis.  In patients suffering from arteriosclerosis with a significant myopia and partial optic atrophy, pollen lowered the level of cholesterol in blood serum and increased the field of vision and stabilized the visual acuity.  Pollen and its extracts are successfully used in postinfarction conditions as well as in systemic circulation disorders and arterial hypertension. Moreover, small doses of pollen given to older people allow both the inhibition of the atherosclerotic changes of blood vessels and improvement of cerebral blood flow.  When bee pollen is given to anemic patients, levels of hemoglobin increase considerably.  It has been reported that honeybee pollen helps regulate cholesterol and triglyceride levels in blood. | |
| Anti-aging effect and Skin protection | Royal jelly | It has believed from ancient times that RJ can prolong life by protecting the DNA and lowering the oxidative stress. RJ increases respiration and oxidative phosphorylation and causes increased activity.  RJ has strogenic and gonadotropic effects in cells.  RJ reduces eye problems, e.g. conjunctivitis, corneal burn and blepharitis high eye blood pressure in old people.  RJ promotes building of collagen in cell cultures.  RJ prevents wrinkles and spots by moisturizing of skin, it reduces melanine synthesis.  RJ prevents from the development of skin lesions such as atopic dermatitis and skin itching. | |
| pollen | Pollen elongated the life span of experimental animals. | |
| Effects on the reproductive system and  fertility | Royal jelly | RJ increases fertility of women and men because it is an important source of para-aminobenzoic RJ exhibits a low estrogenic activity and effects on osteoporosis, perimenopausal symptoms, improving hormonal equilibrium and fertility by increasing sperm and ovules quality.  RJ improves intestinal absorption of calcium in ovariectomized female. | |
|
| Pollen | Demonstrated that egg production and egg mass are slightly increased in laying hens fed diet supplemented with pollen extract.  Found that pollen supplementation at the levels of (0.5, 1, 1.5, 2 and 2.5%) significantly improved cocks reproductive performance.  Bee pollen is confirmed as an interesting resource, able to improve productive and reproductive performance of chicken. | |
| Fortifying and tonic action | Royal jelly | RJ is an ideal food additive for newborn infants. It improves appetite and general conditions, increases weight and hemoglobin and red blood cells in premature babies or with nutritional deficiencies.  RJ increases energy levels, vital capacity, respiratory function and muscular effort capacity; it improved the appetite, the body mass and the strength during malnutrition.  The pantothenic acid (B5) in RJ is converted to coenzyme A (helps the body to metabolize lipids) and improves stress response capacity.  In heart disease patients, RJ increases comfort  Feelings, euphoria, strength and appetite.  In patients with chronic fatigue syndrome, RJ increased the feeling of being energetic.  RJ improves physical performance of humans, weakness and general condition of old people. | |
| Pollen | Bee pollen has also been proposed as a valuable dietary supplement. Animal feeding experiments with pollen have also been carried out. It was proven that mice and rats, fed with pollen, showed a higher vitamin C and magnesium content in thymus, heart muscle, and skeletal muscles as well as a higher hemoglobin content and greater number of red blood cells when compared to animals given standard feed. | |
| Immunomodulatory and anti-alergic activity | Royal jelly | RJ actives against respiratory problems and asthma.  Unsaturated fatty acids, Amino and gamma globulin, enzymes, proteins, hormones vitamin E and A help the immune system fight infections, cancer, allergy and inflammation.  RJ inhibits the formation of metastases.  10HDA and 3-10-dihydroxydecanoic acid stimulate the proliferation of T cells, but, in high concentrations, they inhibit it, decrease IL-2 production and increase IL-10.  MRJP 1 of RJ stimulates the proliferation of monocytes.  The DIII protein of RJ stimulates the growth of lymphocyte cells in serum deprived mediums.  Water extract possesses the most potent immunomodulatory activity.  Oral administration of RJ (1g/kg) :   * inhibited histamine discharge * significantly decreased the serum levels of specific Ig E * lower the macrophage production of PG E2, * improves the Th1/Th2 ration in favor of Th1   RJ increased the number of leucocytes, lymphocytes and antibodies production in chicks.  RJ has inhibited auto-immunity, by dropping of anti-erythrocyte antibodies and of anti-DNA antibodies, and a reduction of the splenic autoreactive B lymphocytes.  In autoimmune hypothyroidism disease RJ plays immunomodulatory role. RJ produces the proliferation of healthy lymphocytes and the increased all blood cells and secretion of gamma-interferon, while decreasing the production of other cytokines.  RJ reduces the levels of the antibodies against the thyroid stimulating hormone receptor (Ac-TSHR). | |
|  | pollen | A new water-soluble bee pollen polysaccharide from *Crataegus pinnatifida Bge* induced phagocytic rates and phagocytic indexes by peritoneal macrophages.  Bee pollen has also been successfully used for oral desensitization of children who have allergies.  Diets supplemented with bee pollen could boost the early development of thymus and fabric bursa, retard the bursa degeneration and promote the immune response of spleen of chickens.  It has also been suggested that pollen could be used for treatment of allergic reactions; when rats were fed 20 mg pollen during five days, IgG levels increased but IgE was restrained in their blood. | |
| Detoxifying action | pollen | The wide-ranging and well-documented studies on animals also unambiguously showed detoxifying action of pollen. The rats were poisoned with organic solvents such as carbon tetrachloride and trichlorethylene, as well as ethionine and ammonium fluoride, both causing a deep damage of liver cells, and galactosamine, which imitate the changes of viral hepatitis, ethanol, and allyl alcohol, which induce steatosis and cirrhosis, and with drugs: paracetamol and hydrocortisone. Under their influence, very high levels of enzymes such as alanine and aspartate transaminase, acid phosphatase, and bilirubin were assayed. Pollen lowered the level of these substances in the blood serum even to physiological values, which proves the therapeutic properties of this product in reference to liver tissue. | |

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