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Fagopyrum esculentum Moench (common buckwheat) edible plant of Himalayas: A Review

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ABSTRACT

*Buckwheat is grown throughout a large area of Asia and Southeast Asia as a crop. Common buckwheat (*Fagopyrum esculentum*) is a crop of secondary importance in many countries. The crop is not a cereal, but the seeds are usually classified among the cereal grains because of their similar usage. The protein of buckwheat is of excellent quality and is high in the essential amino acid lysine, unlike common cereals. Common buckwheat contains high nutritive substances (63% carbohydrate, 11.7% protein, 2.4% fat, 9.9% fiber, 11% water and 2% minerals). Common buckwheat is also important as a nectariferous and pharmaceutical plant, which contains rutin, its consumption has increased tremendously. The review, which covers the cultivation, collection, , concepts, prospects and potential of buckwheat. Finally, we provide a vision for buckwheat.*

KEYWORDS: Buckwheat, Pharmaceutical Plant, Rutin, Phytochemical and Pharmacological.

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INTRODUCTION

India is one of the leading country world wide, blessed with rich and diverse heritage of cultural traditions and wealth of tradition knowledge system related to the use of plant species [1]. Himalaya is one of the richest hot spot of biodiversity.[2] The diverse natural habitats all over the Himalayan region are rich repositories of plant diversity that are used for a variety of purpose i.e. food, fodder, medicine etc.[1] Himalaya has great wealth of medicinal plants and traditional knowledge[3]. There is long history and wide acceptability of traditional medicine. The inhabitant of the region cure various diseases such as cold/cough, fever, liver complaints, kidney stones, joint pain, eye and ear complaints, anaemia, wound healing by the traditional medicine. The different plant part are used in different ratio to cure disease.[1]

The Himalayas region is broadly categorized as: North, central and North-East Himalaya.[4] Central Himalayan region covers the new state of India which comprising the major division of Kumaon and Garhwal.[3] It has been cited in the ancient literature that this region of Garhwal – Kumaun in the Central Himalaya bears the name of Uttarakhand (Uttar = North, Khand = regions).[5] It is a hilly state, which differs in terms of topography, elevation, geographical features, habitat, diversity from the plains.[6] Most of the northern parts of Uttarakhand are covered by high Himalayan ranges and glaciers, due great altitude variation, wide array of climatic zones are available, which favours the luxuriant growth of diversified and rich vegetation.[7] It is a store house of rich variety of herbs, medicine and aromatic plant species.

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The central Himalaya represents a large number of wild edible plant species which constituent a large portion of food in tribal and hilly areas consumed by local inhabitant.Wild edible plant species are helpful in supporting the livehood and also address the economic need.There are large number of wild edible plant species that provides vegetables, fruits and are identified by the inhabitants. The traditional staple food from the food grains are available which fulfills the nutritional requirement in the central Himalayas. There are some vegetable cuisine apart from common vegetable only cooked in the Uttarakand hills, which are seasonal, but have medicinal value.[6] One of such vegetable plant *Fagopyrum esculentum* Moench is also known as common buckwheat. In Hindi it is known as Kotu, Phaphra and in Kumaon as ogal belonging to family Polygonaceae.[8] The name "buckwheat" comes from the Anglo-saxon word *boc* (beech) and *whoet* (wheat) because the seed resembles a small beech nut.[9] Local people in hilly area of Uttarakhand used it in cooking and on the occasion of festivals, and other religious rituals, dishes are prepared out of it [6].

***Fagopyrum esculentum* Moench description**:

Fagopyrum is slender, annual herb 3-5 ft high, stems are red–tinged slender, leaves are broadly triangular and acute upto 7cm long. Fruit is 02-04 inches long with keeled edges varies in colour form silvery grey to brown or black. It is cultivated to obtain grain for human consumptions. It is also grown for livestock and poultry feeds as a green manure, smother crop to crowd out weeds and source of buckwheat honey.[10] It has triangular seeds with black soft hull, light green to white kernel.[11] Flowers are white to pink.[12]

***Fagopyrum esculentum* Moench distribution:**

It is an important crop in some region of the world, not taxonomically related to wheat. Due to its way of cultivation and utilization, it usually grouped with cereals, though not a cereal. It has been used both as a food and a traditional medicine.[13] It is native to central Asia, grows wild in Manchuria and sibera.[10] It is distributed from south of the Himalayas to Bhutan, Nepal, northern India, and northern Pakistan. From China, buckwheat also spread to Korea and Japan.[14] It was introduced into europe from Asia by the crusader hence the common name saracen corn.[15] In India, the crop is widely grown in Jammu and Kashmir in the west, and Arunachal Pradesh in the east. Its high concentration was observed in high mountains of Jammu & Kashmir, Leh, Himachal Pradesh, Garwhal, Kumaon, Darjeeling, Sikkim, Assam, Arunachal Pradesh, Nagaland, Manipur, Nilgiris, Palani hills.[16]

It is a quick growing crop. It grows on the worst and poorest soils. It prefers a moist cool climate and a well drained sand soil. In Northern India, *Fagopyrum esculentum* is usually a rainy season crop. It is sown in July and harvested in October. In Nilgiris, it is generally sown in April and harvested in August.[17]

***Fagopyrum esculentum* Moench(Buckwheat)-Uses**

Traditional Use

Medicinal: *Fagopyrum esculentum* plant is used in house hold remedies. Leaves are cooked in iron vessel are given to anemic patients. This cooked leaves are also used to cure old constipation.[1]

Miscellaneous:*Fagoprum esculentum* (Common buckwheat) is the most widely consumed buckwheat species with its advantages of sweet taste and large, easily de-hulled seed.[9] It is often raised as a leafy vegetable crop in many areas of the Indian subcontinent.[18] The leaves and young shoots are boiled and eaten as spinach. Its perisperms can be used as fuel in producer gas plants. A dye prepared from its hulls is used on textile fabrics.[17] It is useful as a green manure crop for renovation of low-productivity land because it grows well on such land and produces a green manure crop in a short time and

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its cultivation promotes improved soil texture and increases production of fallow crop[16] and also has been used as a smother crop.[18]

It is consumed in many different preparations in different countries. In Japan it is mainly consumed as a noodle soba.[18] The leaf flour is used in Japan as an additive to some food products, for example ice cream and to declare the functionality of the product.[19] In Russia and Poland the groats and flour are used to make porridge and soup. In Sweden it is used to stuff fish. In China it has been reported that buckwheat is used for the production of vinegar. In Southeast Asia buckwheat is a staple food in many hilly areas. In Europe and North America buckwheat flour is generally mixed with wheat flour to prepare pancakes, biscuits, noodles and is used as a meat extender.[18] In eastern Europe roasted groats called roasted kasha are cooked and served like rice. The groats are used in the United State as a breakfast cereal.[20] The tea prepared from buckwheat flowers shows highest content of rutin.[21]

***Fagopyrum esculentum* Moench (Buckwheat)**

Chemical composition

The important component of *Fagopyrum esculentum* is quercetin-3-rhamnoglucoside (rutin), a flavonol glycoside.[22] *Fagopyrum esculentum* can be used as a good source of dietary rutin[23,24,25] because no rutin was found in cereals and pseudocereals accept *Fagopyrum esculentum* (Buckwheat).[19] The presence of rutin content was reported in the processed groats, leaves, and flowers of buckwheat.[21]

Leaves and Flowers:

Rutin (80-90%) present in the leaves and flower,[26] most of the it present during blossoms of plants , only a small percentage is present in the stems and absent in the fruits.[27] The concentration of rutin is more in the higher and younger leaves than older ones. Hyperosid, gallic-3-O-glucoside chlorogenic acid, neochlorogenic acid are present in leaves and stem.[28]

Seeds:

Protein, carbohydrates, fat, fiber, ash are present in fagopyrum esculentum seeds.[11] Seeds contain flavonoids and also tannins (0.5% to 4.5%). Flavonoids contains flavons like quercetin, quercetrin, rutin and anthocyanidins like anthocyanin,[29] isovitexin is also flavonoids in fagopyrum esculentum seed.[30] Rutin and quercetin are main anti-oxidant constituents of its seed extracts and the antioxidant activity of quercetin was higher than that of rutin.[31] The tannins in buckwheat seedbound with monosaccharides, fructose and glucose into tannin-carbohydrate complex.[32] Tocopherols reported in the hexane extract of buckwheat seed components, while methanolic extracts were rich in in phenolic acids and flavonoids.[33]

Grain and Hull:

Fagopyrum esculentum grain contains moisture, protein, fat, mineral matter, fiber, carbohydrates, calcium, and phosphorus. Traces of copper, Nickel, cobalt and zinc, cyanide, phytin, iodine and riboflavin have been reported.[17] It also contain rutin.[13] Its protein are rich in arginine and lysine[34] and comprise 18% albumin, 43% globulin, 1% prolamine and 38% gluetin. Protein concentrate and hydrolysate from *fagopyrum esculentum* can be of potential usefulness as food ingredients.[35]

Fagopyrum esculentum grain and hulls consist of flavonoids and flavons, phenolic acids, condensed tannins, pytosterols and fagopyrin.[34] Rutin ,orientin, vitexin,quercetin, isovitexin and isoorientin present in fagopyrum esculentum hulls.[30] It also contains dry matter, total digest, protein, fat, fiber, mineral matter.[18] It was reported that flavonoids were phenolic compounds in buckwheat hulls responsible for a high antioxidant activity, while those in buckwheat groats are catechins.[35] *Fagopyrum esculentum* may be important source of zinc, copper and manganese.[36]

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Root:

N-feruloltyramine and 7-hydroxy-N-feruloyltyramine are present in the roots and very low concentration in other parts of plant. Protocatechic acid, gentisic-5-O-glucoside, p-hydroxybenzoic acid, p-cumaric and ferulic acid appears in small amount in all parts of plant.[28]

Feed, Straw, Green fodder and Sprout:

Fagopyrum esculentum feed, Straw, Green fodder contains dry matter, total digest, protein, fat, fiber, mineral matter[17] and its sprout contains rutin, isoorientin, and orientin which show antioxidant activity.[37]

Table 1: Average (Percentage) composition of Buckwheat and its by-products.[17]

	Dry matter	Digest protein nutr.	Total digest	Nutr. ratio	Protein	Fat	Fibre	N-free extract	Mineral matter
Grain	90.4	8.9	64.4	6.2	11.9	2.4	10.3	63.8	2.9
Flour	87.5	7.9	86.1	9.9	8.6	1.7	0.7	75.3	1.2
Middlings	88.7	25.8	75.7	1.9	29.7	7.3	7.4	39.4	4.9
Feed	89.1	14.7	59.1	3.0	18.6	5.0	18.3	43.1	4.1
Hulls	90.0	0.1	28.0	27.0	4.3	0.9	44.4	38.3	2.1
Straw	90.1	1.2	32.3	25.9	5.2	1.3	43.0	35.1	5.5
Green fodder	36.6	2.9	21.7	6.5	4.6	0.9	8.0	19.5	3.6

EXPERIMENTAL AND PHARMACOLOGICAL STUDIES

On the basis of various experimental and pharmacological researches, the following medicinal properties of various parts of *Fagopyrum esculentum* (common buckwheat) have been reported.

***Fagopyrum esculentum* Moench(buckwheat) Groat**

Fagopyrum esculentum (Buckwheat) seeds when dehulled i.e. pericarp removed, is referred to as groats.[21]

Methanol extract of *Fagopyrum esculentum* Moench(buckwheat) showed the highest antioxidant activity coefficient of 627±40.0 at 200mg/l when determined by the carotene-bleaching method and longest induction time of 7.0±0.2 h by Rancimat method, when extracted with solvents of different polarities.While acetone extract showed the highest total phenolics of 3.4±0.1 g catechin equivalents/100g and the highest scavenging activity of 78.6±6.2% at 0.1 mg/ml by the DPPH method. The order of antioxidant activity of 0.1 mg/ml *Fagopyrum esculentum* Moench(buckwheat) extract was: Acetone extract > ethanol extract = methanol extract > butanol extract = ethyl acetate extract.[38]

Ethanol extract of *Fagopyrum esculentum* Moench (buckwheat) exhibited high capacity to inhibit self-oxidation of linolic acid(Wo = 0.86) and groats were characterized by a high DPPH(1,1-diphenyl-2 picrylhydrazyl) radical scavenging capacity (80.8%). The capacity to inhibit self-oxidation of linolic acid was determined by spectrophotometry (λ = 234 nm), antioxidant efficiency (Wo) expressed by the ratio of the difference in the increment of absorption in the control and the tested sample to the increment of absorption in the control sample. The DPPH radical scavenging capacity was determined based on changes in the concentration of the stable DPPH radical in relation to the blank test, assessed by colorimetry(λ = 517).[39] The higher phenolic contents in the phenolics rich fractions exhibited the stronger antioxidant capacity than the phenolics less rich fractions and the flour milled from the outer layers of phenolic compounds showed antioxidant capacity are considered to have significant health benefits.[30] Microwave irradiation can be used to obtain *Fagopyrum esculentum* Moench(buckwheat) extracts with higher phenolic content and similar antioxidant activity as extract heated in a water bath.[40] Catechin and rutin showed antioxidant activity, which known as a biological phytochemical in *Fagopyrum esculentum* Moench(buckwheat) groats .The activity of catechin was superior to rutin.[41]

Fagopyrum esculentum Moench(buckwheat) exract exerted an influence on the activity of radical scavenger enzymes that had been diminished under

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conditions of ischemia-reperfusion, and increased the activity of superoxide dismutase, catalase which eliminates hydrogen peroxide and inhibits production of hydroxyl radical (.OH) and (OCl). The extract exerted a protective effect on the enzymes in the body against oxidative stress. It facilitates restoration of function following ischemia-reperfusion injury, a type of circulatory disorder, using an O2 generation system.[42]

Fagopyrum esculentum Moench(buckwheat) extract inhibits progression of renal failure. Extract was given orally at the dose of 100 or 200 mg/kg of body weight/day by stomach tube for 90 consecutive days, showed improvement in mesangial proliferation, extratubular lesions, and tubular interstitial lesions, restored the decreased activities of reactive oxygen species-scavenging enzymes, and decreased serum levels of creatinine and methylguanidine in nephrectomised rats. Hence the extract is beneficial during involment of free radicals in circulatory disturbances.[43]

Fagopyrum esculentum Moench(buckwheat) concentrate is an effective source of D-chiro-inositol (D-CI) for lowering serum glucose concentrations in rats. In fed streptozotocin (STZ) rats,both doses of the buckwheat concentrate(containing 10 and 20 mg of D-CI/Kg of body weight) were effective for lowering serum glucose concentrations by 12-19% at 90 and 120 min after administration. As concentrate was effective source of D-CI for lowering serum glucose concentration in rats and therefore may be useful in the treatment of diabetes.[44]

Fagopyrum esculentum Moench(buckwheat) grain extract has profound anti-allergic potential in mast cell-dependent test models. Extract showed potent inhibitory effect on the compound 48/80-induced vascular permeability when given orally for 3 days, resulting in 82% and 40% inhibition at the dose of 1.0 and 0.1g/kg bodyweight. Intraperitoneal and intradermal administration of extract also inhibited the compound 48/80-induced vascular permeability documented by evans blue extravasation, ketotifen was used as positive control. Extract showed potent inhibitory effect on passive cutaneous anaphylaxis activated by anti-dinitrophenyl IgE when orally administered to rats and also inhibited the IL-4 and TNF-α mRNA induction by PMA and A23187 in human leukemia mast cells. *Fagopyrum esculentum* Moench(buckwheat) grain extract may be applicable to the treatment of allergic inflammation because anti-allergic action of this extract may be due to the inhibition of histamine release and cytokine gene expression in the mast cells.[45]

Fagopyrum esculentum Moench (buckwheat) act as prebiotic food due to the increase in the rat-intestine of lactic acid bacteria, when rats were fed for 30 days with *Fagopyrum esculentum* Moench (buckwheat) diet. In this diet a slight decrease of Enterobactaria and less pathogenic bacteria were observed and *Lacto bacillus acidophilus, Lactobacillus salivarius,* and *Bifidobacterium infantis* were found in both (conventional food and *Fagopyrum esculentum* Moench) diets, only *Lactobacillus plantarum, Bifidobacterium spp* and *Bifidobacterium lactis* were found in *Fagopyrum esculentum* Moench (buckwheat) diet. So *Fagopyrum esculentum* Moench(buckwheat) is a prebiotic food and hence it is a healthy food due to the diminution on total cholesterol, HDL (High Density Lipid) cholesterol and, HDL phospholipids in *Fagopyrum esculentum* Moench diet.[46]

Consumption of *Fagopyrum esculentum* Moench(buckwheat) in rats improves several cardiovascular risk factors induced by obesity in experimental rats. The rats were raised on an obesogenic diet and *Fagopyrum esculentum* Moench(buckwheat) for 4 weeks. *Fagopyrum esculentum* Moench(buckwheat) group showed lower levels of total cholesterol and LDL-C and higher

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HDL-C and also showed large aortic lumen which leads to improve cardiovascular risk factors.[47]

***Fagopyrum esculentum* Moench(Buckwheat)Hull :**

Fagopyrum esculentum Moench(buckwheat) hull extract was effective for protecting biological systems against various oxidative stresses *in vitro*, and to have antioxidant activity *in vivo*. *Fagopyrum esculentum* Moench(buckwheat) hull extract scavenged super oxide anion and strongly inhibited autoxidation of linoleic acid by *in vitro* studies. Thiobarbituraric acid reactive substance and flourescent substance concentration were significantly decreased in blood, liver and brain of the mice when fed a standard diet supplement with *Fagopyrum esculentum* Moench(buckwheat) hull extract for 14 days compared those of non-treated mice.[48]

***Fagopyrum esculentum* (Buckwheat) Seeds :**

Polyphenol-rich *Fagopyrum esculentum* Moench (buckwheat) proteins were unique protein materials for the production of the hydrolysates with excellent antioxidant activities, including DPPH radical scavenging ability, reducing power and the ability to inhibit linoleic acid peroxidation and the antioxidant activity of hydrolysate was closely related to their polyphenol contents. The DPPH activity was determined by Shimada, Fujikawa, Yahara and Nakamura. The hydrolysate at various concentration (0-1.0mg/ml) showed dose dependant DPPH radical scavenging inhibition and the DPPH radical inhibition for all the hydrolysate was lower than that of Trolox(control). The reducing power of the hydrolysates was evaluated by the method developed by Oyaizu.The dependence of the reducing power of the hydrolysate on concentration was similar to ascorbic acid (antioxidant). The reducing power of the hydrolysates at the highest experimental concentration(5 mg/ml) was in the range of 0.77-1.24 which was higher than 0.08-1.24 reported for similar concentration of haemoglobin. The inhibition of linoleic acid peroxidation of hydrolysates or antioxidants(Trolox and butylated hydroxytoluene) was evaluated by the thiocyanate method.The inhibition activity of all the hydrolysates was similar to that of Trolox.[27]

The ethanol extracts of *Fagopyrum esculentum* Moench (buckwheat) seeds also showed DPPH free radical- scavenging effect. Its extracts effectively scavenge free radicals and their DPPH free radicals scavenging capacities appeared dosage dependantly. Electro-spray MS analysis showed that the major constituents in the ethanol extracts of *Fagopyrum esculentum* Moench (buckwheat) seeds were rutin and quercetin and the anti-oxidative activity of quercetin was higher than that of rutin[26]. Rutin plays an important role in antioxidant activity of *Fagopyrum esculentum* Moench (buckwheat) seed which showed protective effect against lipid peroxidation.[49]

Fagopyrum esculentum Moench(buckwheat) protease inhibitors designated BWI-1 inhibits trypsin, chymotrypsin and subtilisin whereas the *Fagopyrum esculentum* Moench(buckwheat) protease inhibitors designated BWI-2a inhibits only trypsin. Both the inhibitors significantly suppressed the growth of lymphoblastic leukemia cell as judged by the soluble 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide(tetrazolium/formazan assay). Chemical modification of Arg residue I inhibitors by 1,2-cyclohexandione inactivated their trypsin inhibitory activity, abolishing their suppressive activity. BWI-1and BWI-2a can induce apoptosis in T-acute lymphoblastic leukemia cells, with DNA fragmentation.[50]

Tannins from *Fagopyrum esculentum* Moench (buckwheat) showed antibacterial activity against *Listeria monocytogenes*. Antibacterial activity (minimum inhibitory concentration, MIC) was determined by the broth dilution method. A wide range of antibacterial activities ranging from MICs of 62.5 to 500 µg/ml of *Fagopyrum esculentum* Moench (buckwheat) was apparent and shown relative high

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levels of activity at 62.5 µg/ml from *Fagopyrum esculentum* Moench (buckwheat) against *Listeria monocytogenes.*[51]

***Fagopyrum esculentum* Moench(Buckwheat) Herb**

An extract from *Fagopyrum esculentum* Moench (buckwheat) had significantly better antioxidant activity by DPPH assay and prevented more effectively the UV-induced peroxidation of linolic acid than rutin or commercial UV absorber .[52] It was reported that phenolics were the dominant antioxidant constituents of the *Fagopyrum esculentum* Moench (buckwheat) so contents of the total phenolic and flavonoids of *Fagopyrum esculentum* Moench extracts shows goods antioxidant activity.[53]

Oral administration of germinated *Fagopyrum esculentum* Moench (buckwheat) extracts suppressed excessive body weight gains and improved lipid profile in serum and liver in a dose-dependent manner. Anti-fatty liver activity of germinated *Fagopyrum esculentum* Moench (buckwheat) seemed to be induced by down-regulating PPARγ and C/EBPα expression in hepatocytes.[54]

Raw *Fagopyrum esculentum* Moench (buckwheat) extract and germinated *Fagopyrum esculentum* Moench (buckwheat) extract decreases blood pressure and prevented an increase in the content of 3-nitrotyrosine, a biomarker of peroxynitrite, in the aorta of spontaneously hypertensive rats when given every day for 5 weeks. In the 300mg/kg both the extract treated groups, the blood pressure was not changed during experimental periods but the systolic blood pressure was significantly decreased time-dependently when given at dose of 600mg/kg raw *Fagopyrum esculentum* Moench (buckwheat) extract and germinated *Fagopyrum esculentum* Moench (buckwheat) extract. The systolic blood pressure began to decrease at 4 weeks after treatment. Germinated *Fagopyrum esculentum* Moench (buckwheat) extract has a higher potential antihypertensive effect than raw buckwheat extract in spontaneously hypertensive rats, and protects aortic endothelial cells from oxidative damage.[55]

***Fagopyrum esculentum* Moench (Buckwheat) sprouts:**

An extract of *Fagopyrum esculentum* Moench (common buckwheat) sprouts may be a useful material for treatment or prevention of the progress of inflammatory diseases as it showed siginificant anti-inflammatory activity *in vitro* and *in vivo*. Oral administration of lipopolysaccharide in mice confirms the anti-inflammatory activity of extract of *Fagopyrum esculentum* Moench (common buckwheat) sprouts. Inflammatory cytokines were markedly up-regulated in the spleen and liver from lipopolysaccharide–administrated mice, where as combination treatment with lipopolysaccharide and extract decreased up-regulation of them in cytokines because this extract blocks all the gene expression induced by lipopolysaccharide treatment.[56]

Extract of the edible parts of *Fagopyrum esculentum* Moench (common buckwheat) sprouts showed free radical-scavenging activities, so are recommended for their high antioxidative activity and excellent dietary source of phenolic compounds. The edible parts of sprouts were analysed for their free radical activity by DPPH assay.[57] The superoxide anion radical-scavenging activities of phenolic compounds in *Fagopyrum esculentum* Moench (common buckwheat) sprouts and their content indicated that rutin, isoorientin and orientin contributed to the super oxide radical-scavenging-like activity of extract.[37] In contrast Liu C. reported that ethanol extracts of *Fagopyrum tataricum* Gaerth sprouts had higher reducing power, free radical scavenging activity, and superoxide anion scavenging activity than those of *Fagopyrum esculentum* Moench (common buckwheat) sprouts. But both *Fagopyrum tataricum* Gaerth sprouts and *Fagopyrum esculentum* Moench (common buckwheat) sprouts could decrease the

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production of intracellular peroxide and remove the intracellular superoxide anions in HepG2 cells.[58]

***Fagopyrum esculentum* Moench (Buckwheat) leafs and flowers:**

The supplementation of the powdered *Fagopyrum esculentum* Moench (common buckwheat) leaf flower mixture was rich in phenolic compounds and fibre, seemingly suppressed the body weight gain and lowered plasma and hepatic lipid concentrations with a simultaneous increase in faecal lipids in rats fed a high-fat diet. Rats were divided into three groups: normal control, high-fat, and high-fat supplemented with mixture of powdered *Fagopyrum esculentum* Moench (common buckwheat) leaf and flower groups. An efficacy test of lipid-lowering action of the mixture, suggests that these plant parts would be beneficial for regulation of lipid metabolism or prevention of hyperlipidemia in experimental animal models.[59] Administration of *Fagopyrum esculentum* Moench (common buckwheat) leaf extracts to high fat diet-fed rabbits for 12 weeks, significantly lowered the hepatic tissue total cholesterol, triglycerides and malondialdehyde. The leaf extract also increased serum testosterone levels along with lowering of serum insulin levels.[60]

It has been suggested that rutin from *Fagopyrum esculentum* Moench (common buckwheat) flowers and leaves might have protective effects on cardiac hypertrophy. Angiotensin II caused significant increase in cell surface area and proliferation of cardiac fibroblast in comparison to control group. Rutin significantly decreased myocyte cell surface and protein synthesis rate, inhibited the proliferation of fibroblasts and hence exhibited a strong inhibition on the hypertrophy and proliferation. Rutin could inhibit cardiac hypertrophy induced by Angiotensin II. [61] It have been reported that there is lowering of blood glucose and improvement in insulin resistance in type 2 diabetic rats induced by tetraoxypyrimidine and fat milk on administration of flavones of *Fagopyrum esculentum* Moench (common buckwheat) flowers and leaf.[62]

Antioxidant activity of *Fagopyrum esculentum* Moench (buckwheat) seeds and leaves proved to be higher when compared with those of oats, barley, *Fagopyrum esculentum* Moench (buckwheat) straws and hulls. Antioxidant activity of leaves was found superior to antioxidant activities of seeds, dehulled seeds, straws and hulls. The leaves proved a higher than triple antioxidant activity when compared with seeds, whereas the straws and hulls had lower antioxidant activities than seeds. Methanol extract of buckwheat seeds showed higher antioxidant activity in comparison with petrolether extract. *Fagopyrum esculentum* Moench (buckwheat) seeds and leaves proved to be suitable food component with antioxidant effect.[52]

The rats receiving the diet containing 90 parts of ground *Fagopyrum esculentum* Moench (common buckwheat), 5 parts of hardened cotton-seed oil, lard 2, salt 2 and a few drops of cod-liver oil daily were exposed in front of a window, especially in month of may and june showed high degree of sensitiveness not shown by control. When the husk was removed from the meal before incorporation in the diet, no sensitivity of light was observed. Examination of different portion of growing *Fagopyrum esculentum* Moench (buckwheat) plant showed that dried leaves, given in doses upto 0.32 g. daily for 5 weeks has no effect on rats, while dried flowers in doses of 0.1-.2 g. produce highly sensitive animal when exposed to sunshine.[63]

***Fagopyrum esculentum* Moench (Buckwheat) Honey :**

Fagopyrum esculentum Moench (buckwheat) honey increase serum antioxidant capacity in humans. The acute effect of consumption of water, water with 160g/L *Fagopyrum esculentum* Moench (buckwheat) honey, black tea, black tea with 160g/L *Fagopyrum esculentum* Moench (buckwheat) honey, black tea

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with sugar on serum oxidative reactions was examined in 25 healthy men. Antioxidant capacity of human serum samples was measured using different methods: the oxygen radical absorbance capacity (ORAC) asssy, ex vivo susceptility of serum lipoprotein to Cu^{2+}-induced oxidation, and the thiobarbituric acid reactive substance(TBARS) assay. The serum antioxidant capacity determined by ORAC increased significantly by 7% following consumption of *Fagopyrum esculentum* Moench (buckwheat) honey in water.[64]

Fagopyrum esculentum Moench (buckwheat) honey (New York, US) showed pronounced *in vitro* activities leading to decreased levels of oxidants, including radicals when compared with honeys from other floral sources. *Fagopyrum esculentum* Moench (buckwheat) honey was selected for use in wound-healing products as most effective in reducing ROS(reactive oxygen species) level and show major antioxidant activity due to phenolic constituents present in relative large amount. Its phenolic compounds may also exert antibacterial activity, where as its low pH and high free acid content may assist wound healing.[65]

***Fagopyrum esculentum* Moench (Buckwheat) Flour :**

Dietary protein *Fagopyrum esculentum* Moench (buckwheat) flour caused a significant decrease in liver cholesterol, where as dietary *Fagopyrum esculentum* Moench (buckwheat) protein extact caused slight decrease in rats when fed for 10 days. Consumption of protein *Fagopyrum esculentum* Moench (buckwheat) flour for 10 days significantly suppressed adipose tissue weight and hepatic activity activity of fatty acid synthase in rats fed cholesterol-free diets as compared with consumption of casein, whereas *Fagopyrum esculentum* Moench (buckwheat) protein extact for this period caused only a slight decrease in adipose tissue weight. Both the protein from flour and extract significantly decreased the incidence of cholesterol gallstones and lithogenic index with increased fecal excretion of acidic steroids in mice fed cholesterol-enriched diets for 27 days. Protein *Fagopyrum esculentum* Moench (buckwheat) flour has strong cholesterol-and body fat lowering activities in rats and gallstone formation-suppresing activity in mice.[66]

The flour of *Fagopyrum esculentum* Moench (buckwheat) shows a higher antioxidant activity than in the hull by hydrogen peroxide(H2O2) scavenging, hypochlorous acid scavenging (HOCl) and superoxide anion scavenging(O2). H2O2 scavenger was measured according to Pick and Keisari, HOCl produced by chlorination of taurine was measured according to Weiss et al., whereas superoxide anion was generated by the hypoxanthine-xanthine oxidase system by Aruma et al.[67]

Fagopyrum esculentum Moench (buckwheat) crackers exhibited significantly higher antioxidant activity(radical scavenging activity on 1,1-diphenyl-2-picrylhydrazyl radicals-DPPH) when compared with wheat crackers as according to their IC50 values. DPPH scavenging activity of crackers could have been partly due to presence of rutin which possesses strong ability to scavenge DPPH. So crackers made from *Fagopyrum esculentum* Moench (buckwheat) flours may be regarded as health-promoting functional foods, especially for celiac disease patient [70]. The antioxidant potential of the *Fagopyrum esculentum* Moench (buckwheat) protein was compared by assessing their capacity to scavenge2,2'-azinobis(3-ethylbenzothiszoline-6-sulphonic acid) and hydroxyl radicals. Free radical scavenging activity of *Fagopyrum esculentum* Moench (buckwheat) protein was accentuated by *in vitro* digestion, especially after 2 h pancreatin digestion following the 1 h pepsin treatment. Fractions enriched with di-, tri- and tetrameric peptides containing tryptophan and proline of *Fagopyrum esculentum* Moench (buckwheat) protein exhibited the strongest

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radical scavenging activity. These short peptides are implicated in the protection of the upper digestive tract of humans from oxidative stresses.[68]

The ingestion of dough prepared from *Fagopyrum esculentum* Moench (buckwheat) flour resulted in the increase in the concentration of NO in the air expelled from the stomach. This flour when suspended in acidified saliva or in acidic buffer solution in presence of nitrite reduces nitrous acid to nitric acid by proanthocyanidins in the *Fagopyrum esculentum* Moench (buckwheat) and this increase concentration of nitric acid can improve the activity of stomach which helps the digestion of ingested food and the nitration and nitrosation of the proanthocyanidins could contribute to the scavenging of reactive nitrogen oxide species generated from NO and nitrous acid.[69]

A compound isolated from *Fagopyrum esculentum* Moench (buckwheat) flour inhibited angiotensin-I converting enzyme (ACE). This compound is thought to be the hydroxyl derivative of nicotianamine and a very high inhibitory activity towards Angiotensin-I converting enzyme was shown by this hydroxy derivative of nicotianamine from *Fagopyrum esculentum* Moench (buckwheat) flour.[70]

Feeding of *Fagopyrum esculentum* Moench (buckwheat) protein extract showed effect on hepatic and plasma lipids, fat pad weights and activities of enzymes relating to lipid metabolism in tissues of rats. Rats were fed a semipurified diet containing either *Fagopyrum esculentum* Moench (buckwheat) protein extract or casein for 3 days. Hepatic triglyceride concentration and the weights of epididymal and perirenal fat pad were significantly lower in rats fed *Fagopyrum esculentum* Moench (buckwheat) protein extract compared with those fed casein diet. Protein extract also lowers activities of hepatic glucose-6-phosphate dehydrogenase and fatty acid synthase, but did not effect activity of hepatic carnine palmitoyltransferase I and also increases in fecal fat and nitrogen. So feeding *Fagopyrum esculentum* Moench (buckwheat) protein extract causes reductions in hepatic triglyceride concentration and fat pad weights, and suggested that these reductions might be ascribed to lower activities of hepatic lipogenic enzymes and to lower digestibility of fat and protein. Analysis of plasma free amino acids showed marked increases of glycine and arginine in rats fed *Fagopyrum esculentum* Moench (buckwheat) protein extract compared with rats fed casein.[71]

Fagopyrum esculentum Moench (buckwheat) protein extract ameliorates atropine-induced constipation in rats. The rats were fed the diet containing *Fagopyrum esculentum* Moench (buckwheat) protein extract or casein for 8 days, where as atropine(0.5mg/kg weight) or saline on 1st and 8th day. Feeding of *Fagopyrum esculentum* Moench (buckwheat) protein extract diet ameliorated the constipation induced by atropine compared to that of casein diet. It could represent a useful agent for the the treatment of undesirable constipation.[72]

Consumption of a *Fagopyrum esculentum* Moench (buckwheat) protein extract retards 7,12-Dimethylbenz(α) anthracene (DMBA)-induced mammary carcinogenesis in rats. The female rats (20 per diet group) were fed on the experimental diet containing either casein or *Fagopyrum esculentum* Moench (buckwheat) protein extract for 61 days, and DMBA was given orally at the dose of 30mg/kg body weight 2 days before the rats given the experimental diet. *Fagopyrum esculentum* Moench (buckwheat) protein extract intake retards the mammary carcinogenesis by a mechanism involving lower concentration of serum estradiol in rats.[73]

Fagopyrum esculentum Moench (buckwheat) protein extract induce muscle hypertrophy which may be associated with higher muscular strength or physical performance. When the rats were fed on a diet either casein or *Fagopyrum esculentum* Moench

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(buckwheat) protein extract as the protein source (10%, 20% or 30%) for 5 weeks, the relative weights of the gastrocnemius, plantaris and soleus muscles were higher in the *Fagopyrum esculentum* Moench (buckwheat) protein extract-fed animals than the casein-fed, where as when the rats were fed on either a casein or *Fagopyrum esculentum* Moench (buckwheat) protein extract diet at the 20% protein level for 5 weeks, *Fagopyrum esculentum* Moench (buckwheat) protein extract intake elevate the gastronemius muscle weight, carcass protein and water, and reduced carcass fat. It was demonstrated that muscle hypertrophy, elevates carcass protein and water, and reduces body fat by the *Fagopyrum esculentum* Moench (buckwheat) consumption.[74]

Rats fed on a cholesterol-free diet has demonstrated that *Fagopyrum esculentum* Moench (buckwheat) protein product suppressed the plasma cholesterol level more strongly than soy protein isolate (SPI) by enhancing the excretion of neutral steroids and bile acids. The rats were fed on the appropriate experimental diet for 8 weeks. Plasma concentration of total cholesterol and HDL in the *Fagopyrum esculentum* Moench (buckwheat) protein group was lower than casein group, but same in soya protein isolate and casein groups. The excretion of fecal neutral and acidic steroids was markedly higher by the *Fagopyrum esculentum* Moench (buckwheat) protein group than by the casein and SPI groups. These results suggested that *Fagopyrum esculentum* Moench (buckwheat) protein enhanced the fecal excretion of both neutral and acidic steroids by rats, leading to marked hypocholesterolemic activity.[75]

Insoluble fraction of *Fagopyrum esculentum* Moench (buckwheat) protein processing cholesterol-binding properties that reduce micelle cholesterol solubility and uptake by caco-2 cells. *Fagopyrum esculentum* Moench (buckwheat) protein(0.2%) was incubated with cholesterol and micelle lipid components prior to micelle formation, cholesterol solubility was reduced 40%. But cholesterol solubility was not decreased when it was incubated after micelle formation. Reduction in cholesterol uptake in Caco-2 cells was dose-dependent, with maximum reduction at 0.1-0.4% *Fagopyrum esculentum* Moench (buckwheat) protein. In experiment of cholesterol-binding, 83% of cholesterol was associated with an insoluble *Fagopyrum esculentum* Moench (buckwheat) protein fraction, indicating strong cholesterol-binding capacity that disrupts solubility and uptake by Caco-2 cells. The cholesterol-binding properties of a *Fagopyrum esculentum* Moench (buckwheat) protein improves cardiovascular risk factor when used in functional foods. [76]

Feeding of *Fagopyrum esculentum* Moench (buckwheat) protein suppresses 1,2-dimethylhydrazine(DMH)-induced colon carcinogensis. Rats were fed the diet containing either casein or *Fagopyrum esculentum* Moench (buckwheat) protein product (net protein level, 200g/kg; each group, 20 rats) for 20 days. The rats were weekly ingested with DMH for the intial 8 weeks. Dietary *Fagopyrum esculentum* Moench (buckwheat) protein product caused a 47% reduction in the incidence of colon adenocarcinoma. Hence reduction of cell proliferation and expression of *c-myc* and *c-fos* proteins in colonic epithelium by consumption of *Fagopyrum esculentum* Moench (buckwheat) protein product suggest that dietary *Fagopyrum esculentum* Moench (buckwheat) protein product has a protective effect against 1,2-dimethlhydrazine-induced colon carcinogenesis in rats by reducing cell proliferation.[77]

***Fagopyrum esculentum* Moench (Buckwheat) extract :**

Fagopyrum esculentum Moench (buckwheat) polyphenol (600mg/kg, for 21 days p.o.) significantly ameliorated not only the impairment of spatial memory in the 8-arm radial maze, but also necrosis and TUNEL-positive cells in the hippocampal CA1

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area subjected to repeated cerebral ischemia in rats. A 14-day polyphenol treatment significantly inhibited the excess release of glutamate after second occlusion and also suppresses a delayed increase in NOx^- induced by repeated cerebral ischemia in the dorsal hippocampus. So *Fagopyrum esculentum* Moench (buckwheat) polyphenol might ameliorate spatial memory impairment by inhibiting glutamate release and the generation of NOx^- in rats subjected to repeated cerebral ischemia. [78]

Fagopyrum esculentum Moench (buckwheat) extract suppresses the cellular damage induced by β-amyloid(20μM) more potently than Kudincha extract(100μg/ml). Extract (600mg/kg) significantly suppresses the increase in errors induced by scopolamine(0.5mg/kg i.p) in the eight-arm radial maze and protects against cholinergic dysfunction. Hence *Fagopyrum esculentum* Moench (buckwheat) extract exhibit a greater inhibition of β-amyloid-induced neurotoxicity and scopolamine-induced impairment of spatial memory,and may be more effective in Alzheimer's disease, which is related to cholinergic dysfunction.[79]

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