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Jackfruit: Functional component related with human health and its application in food industry

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Abstract

Jackfruit is extensively used in ayurveda traditionally as a cooling tonic and pectoral, roots in diarrhea and fever, leaves to activate milk in women and animals, as a source to treat antisiphilic and vermifuge, leaf ash applied to ulcers wounds and the warmed leaves have healing properties if pasted on the wounds. Jackfruit is reported to have medicinal properties like antioxidant, cardioprotective, anti-inflammatory. The jackfruit bulb and jackfruit seeds are good sources of protein, starch, and minerals. Jackfruits also contain phytonutrients i.e., lignans, isoflavones and saponins and they have numerous health benefits such as anticancer, antiaging, and antioxidant. An activity of certain phytochemicals along with their antioxidant properties further supports the cause of commercial utilization of the fruit. The jackfruits and fruit products hold potential in the diet as they possess not only pleasant taste but also source of naturally and readily available source of instant energy. This review presents a scientific overview of jackfruit with reference to relevant nutritional characteristics, bioactive compounds and its health benefits as well as its use in food industry.

Keywords: Jackfruits, phytonutrients, starch, antioxidants

Introduction

A bioactive compound is a compound having some biological activity. A bioactive compound (or substance) has its direct physiological or cellular effects on a living organism. These compounds can be defined as secondary plant metabolites eliciting pharmacological or toxicological effects in humans and animals (Walia *et al.*, 2019)^[43]. Bioactive compounds are primarily found in fruits. It includes flavonoids, polyphenols, anthocyanins, tannins, betalains, carotenoids, plant sterols and glucosinolates having antioxidant properties.

Jackfruit (*Artocarpus heterophyllus*) belongs to the Moraceae family, native to India and seen abundant in Western Ghats, a biodiversity spot of India. Besides India, jackfruit is commonly grown in home gardens of tropical and subtropical countries especially in Sri Lanka, Bangladesh, Burma, Philippines, Indonesia, Thailand, Malaysia, and Brazil. In India, it is widely distributed in the states of Assam, West Bengal, Uttar Pradesh, Maharashtra, Kerala, Tamil Nadu, and Karnataka and considered to be the "Poor man's food (Jagadeesh *et al.*, 2007^[26] and Baliga *et al.*, 2011^[6]).

It is a medium-size tree typically reaching 28–80 ft. in height that is easily accessible for its fruit. The fruit is cauliflorous in bearing habit. There are two varieties of jackfruit in India: one is small, fibrous, soft and mushy with sweet carpels and a texture like that of raw oysters, and is called Barka and the other variety is crisp and crunchy, but not very sweet called Kapa (Swami *et al.*, 2012^[48] and Noor *et al.*, 2014^[36]).

Jackfruit possess many medicinal properties having innumerable variations in bulb sweetness, acidity, flavor, and taste are observed in jackfruit growing areas. Considering the vast diversity among jackfruit types in Western Ghats offers tremendous scope for improvement of this crop by selection (Sammadar *et al.*, 1985)^[42]. Jackfruit is reported to have medicinal properties like antioxidant, cardioprotective, anti-inflammatory (Prakash *et al.*, 2009^[40]; Swami *et al.*, 2012^[48]). Apart from its medicinal properties jackfruits are processed into baby food, juice, jam, jelly, candies, fruit-rolls, marmalades, ice cream and base for cordials (Oktavia *et al.*, 2017^[37]; Vidyadhara *et al.*, 2017^[52]; Fang *et al.*, 2008^[17] and Omar *et al.*, 2011^[38]). In recent years, there has been increased interest of consumers, researchers and the food industries. The food products can help to maintain health; and the plays role in the prevention and treatment of many illnesses has become widely accepted. This review describes an overview of the functional, nutritional, medicinal and health aspects of jackfruit and its various parts.

Nutritional Characteristics of Jackfruit

The nutritional and phytochemical composition among jackfruit varies depending on the cultivar as well as region. It is a good source of vitamins (A, C, thiamine, riboflavin, niacin) and minerals (calcium, potassium, iron, sodium, zinc) (Swami *et al.*, 2012) [48]. The nutritional characteristics of jackfruit bulb, seed and other part are elaborated.

Jackfruit Bulbs

Jackfruit is heavy and bulky and actual recovery of bulbs or edible portion varies from 20 to 25% which is easily digestible. A 100g portion of edible raw jackfruit provides about 95 calories and is a good source of the antioxidants and vitamin C, providing about 13.7 mg. The fruit is also rich in vitamin B6, potassium, calcium, and iron. The bulb of ripe jackfruit is eaten fresh and used in fruit salads. It possesses high nutritional value; every 100g of ripe fruit pulp contains 18.9g carbohydrate, 1.9g protein, 0.1g fat, 77% moisture, 1.1g fiber, 0.8g total mineral matter, 20mg calcium, 30mg phosphorus, 500 mg iron, 540 IU Vitamin A, 30mg thiamine and 84 calories (Sammadar *et al.*, 1985) [42]. The jackfruit bulb consists of 107.98 total carotenoids (De Faria *et al.*, 2009) [15]. Jackfruit consists of all trans- β -carotene which is an important antioxidant for human health (Haq N 2006) [23].

Table 1: Composition of jackfruit bulb (100 g edible portion)

Sr. No.	Composition	Young Fruit	Ripe Fruit
A. Proximate analysis			
1.	Water (%)	76.2 – 85.2	72.0 – 94.0
2.	Protein (%)	2.0 - 2.6	1.2 - 1.9
3.	Fat (g)	0.1- 0.6	0.1 - 0.4
4	Carbohydrate (g)	9.4 -11.5	16.0 - 25.4
5	Fiber (g)	2.6 – 3.6	1.0 – 1.5
6	Sugars (g)	-	20.6
B. Minerals and vitamins			
1	Total minerals (g)	0.9	0.87- 0.9
2	Calcium (mg)	30.0 - 73.2	20.0 - 37.0
3	Magnesium(mg)	-	27.0
4.	Phosphorus (mg)	20.0 – 57.2	38.0 – 41.0
5.	Potassium (mg)	287 – 323	191 – 407
	Sodium (mg)	3.0 – 35.0	2.0 – 41.0
7	Iron (mg)	0.4 – 1.9	0.5 – 1.1
8	Vitamin A (IU)	30	175 – 540
9	Thiamine (mg)	0.05 – 0.15	0.03 – 0.09
10	Riboflavin (mg)	0.05 – 0.2	0.05 – 0.4
11	Vitamin C (mg)	12.0 -14.0	7.0 - 10.0

(Narasimham *et al.*, (1990) [35], Arkroyd *et al.*, (1996) [3] and Gunasena (1996) [21]

Jackfruit Seed

The jackfruit seeds are around 10–15% of the total fruit weight and have high carbohydrate and protein contents. There are 100-500 seeds in a single fruit. Seeds are normally discarded or steamed and eaten as a snack or used in some local dishes. The fresh seeds cannot be kept for a long time, seed flour can be an alternative product, which can be used in some food products. The jackfruit seeds are a good source of starch (22%) and dietary fiber (3.19%).

Jackfruit seeds contain lignans, isoflavones and saponins that are called phytonutrients and their health benefits are wide-ranging from anticancer to antihypertensive, antiaging, antioxidant, antiulcer, etc.

Table 2: Composition of jackfruit seed (100g edible portion)

Sr.no.	Composition	Value	Sr. no.	Composition	Value
A	Proximate analysis		B	Minerals and vitamins	
1	Water (g)	51.0 – 64.5	1	Total minerals (g)	0.9 – 1.2
2	Protein (g)	6.6 – 7.04	2	Calcium (mg)	50.0
3	Fat (g)	0.40 – 0.43	3	Magnesium (mg)	54.0
4	Carbohydrate (g)	25.8 – 38.4	4	Phosphorus (mg)	38.0 – 97.0
5	Fiber (g)	1.0 – 1.5	5	Potassium (mg)	246
6	Total sugars (g)	-	6	Sodium (mg)	63.2
			7	Iron (mg)	1.5
			8	Vitamin A (IU)	10 – 17
			9	Thiamine (mg)	0.25
			10	Riboflavin (mg)	0.11– 0.3
			11	Vitamin C (mg)	11.0

(Narasimham *et al.*, (1990) [35], Arkroyd *et al.*, (1996) [3], Gunasena (1996) [21] and Azad AK (2000) [5].

The jackfruit seeds have medicinal properties. The oval, oblong, or oblong ellipsoid or rounded-shape, light brown color jackfruit seeds are nutritious and rich in potassium, fat, carbohydrates and minerals. Manganese and magnesium elements have also been detected in seed powder (Barua AG and Boruah BR (2004) [8]. Table 2 shows the composition of jackfruit seed. Seeds contain two lectins, namely jacalin and artocarpin. Jacalin has been proved to be useful for the evaluation of the immune status of patients infected with human immune deficiency virus- 1(Haq N. 2006) [23]. Amylose content of jackfruit seed starch was 32 per cent (Tulyathan *et al.*, 2002) [51]. Jackfruit seed extract was found to inhibit the proteolytic activities of different animal pancreatic preparations effectively (Bhat AV and Pattabiraman TN 1989) [8]. The fresh seed contains crude proteins (606g), fat (0.4g), carbohydrates(38.4g), fiber (1.5g), ash (1.25–1.50g), and moisture (51.6–57.77g), respectively (Morton J. 1987) [32].

Gupta *et al.*, (2011) [22] analyzed phytochemical content of jackfruit seeds found high quantity of saponins (6.32± 0.098 g/100g). Saponins have been known for their medicinal uses, including antispasmodic activity and toxicity to cancer cells. Some alkaloids function as spasmolytic, anticholinergic and anesthetic agents. The alkaloid content in jackfruit seeds was found to be 1.16± 0.09g/100g. Polyphenolics are known to function as antioxidants through a number of mechanisms including radical scavenging by H-donation, prevention of chain initiation by donating electrons or binding of transition metal ion catalysts. Flavonoids prevent platelet stickiness and hence platelet aggregation.

Health Benefits

The health benefits of jackfruit are still underway. The jackfruit bulb and jackfruit seeds are good sources of protein, starch, and minerals. Jackfruits also contain phytonutrients i.e., lignans, isoflavones and saponins and they have numerous, health benefits such as anticancer, antiaging, and antioxidant. Fig.1shows the nutraceutical characteristics of jackfruit bulb and its effect on various diseases.

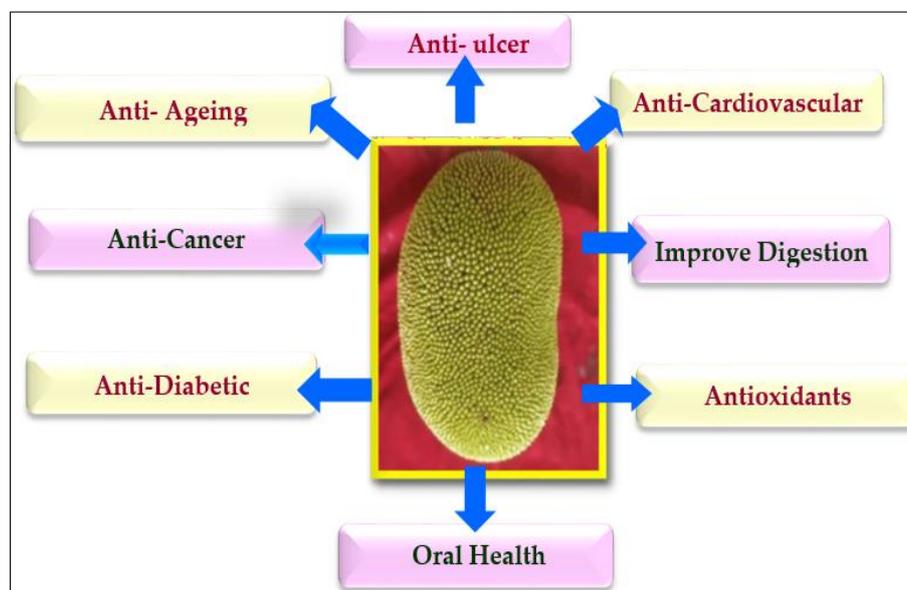


Fig 1: Principal functional and medicinal effects of jackfruit

Table 3: Health benefits of Jackfruit bioactive compounds.

Bioactive compounds	Health benefits
Phytonutrients Lignans, isoflavones, saponins & niacin	Cancer, Hypertensive, Ulcer, Aging, Nerve function, Asthma
Phenolic Compounds	Chronic disease, hyperglycemia
Carotenoid All-trans- β , α , lutein, neoxanthin, 9-cis-violaxanthin carotene.	Inflammation, cardiovascular disease, cataract, age-related macular degeneration
Antioxidants Vit E, Vit C, Vit A, β -carotene, selenium, α -lipoic acid and glutathione.	Coronary heart disease, Hypertension, Lung & Prostate cancer

(Swami *et al.*, 2018) ^[49]

Anticancer

The recent studies show all phytonutrients in jackfruit bulbs have anticancer benefits. The main role of these nutrients is to prevent the harmful free radicals that have been known to develop cancer and many other chronic diseases. The phytonutrients prevent the very initial stage of cancer cell formation. Saponins are also strong anticancer agents. According to a study, saponins show colon cancer preventative properties. These phytonutrients have been found to induce mitotic arrest in the case of leukemia cells. The study also found that it helped in some cases to cause remission. Saponins were found to react to the outer layers of cancer cells (Oktavia *et al.*, 2017) ^[37]. Two important groups of phytoestrogens that are present in jackfruit pulp are isoflavones and lignans (Swami *et al.*, 2012) ^[48]. According to studies, these nutrients help in reducing the risk of endometrial cancer. Jackfruit is rich in fiber. It also has a unique sticky form. Both these properties combine together to work as a great colon cleanser. It helps in removing toxins from your digestive tract. This further helps in reducing the risk of colon cancer.

Antidiabetics

Diabetes mellitus is a metabolic disorder characterized by hyperglycemia resulting from defects in insulin action, insulin secretion or both. The most common type of diabetes mellitus is type 2 diabetes mellitus, which accounts for 85–95% of all cases and constitutes a major public health problem (Cheplick *et al.*, 2010) ^[12]. Hot water extract of mature jack leaves is

recommended by Ayurvedic and traditional medical practitioners as a treatment for diabetes mellitus (Fernando *et al.*, 1991) ^[19]. It is already indicated that an extract of jackfruit improves the glucose tolerance in normal human subjects and diabetic patients (Chavkrewarthy *et al.*, 1991) ^[12]. Jackfruit contains vitamin A, vitamin C, thiamin, riboflavin, niacin, calcium, potassium, iron, manganese, and magnesium among many other nutrients. It is good for diabetes as they improve insulin resistance.

Immune System

Jacalin. The major protein from the jackfruit seeds, is a tetrameric two-chain lectin combining a heavy chain of 133 amino acid residues with a light β chain of 20–21 amino acid residues (Kumar *et al.*, 1982) ^[28]. Jacalin's uniqueness in being strongly mitogenic for human CD4 + T lymphocytes has made it a useful tool for the evaluation of the immune status of patients infected with human immune deficiency virus HIV-1 (Pereira-da-Silva *et al.*, 2006) ^[39].

Improve Digestion

The presence of high fiber (3.6 g/100 g) in the jackfruit prevents constipation and helps in smooth bowel movements. These fibers also offer protection against colon mucous membrane by removing or driving away the carcinogenic.

Dental Health

Rao *et al.*, (2014) ^[41] reported that the jackfruit latex extract which is rich in flavonoids and alkaloids was checked for

antibacterial and antifungal properties which shows fairly well and significant comparison with standard antibacterial and antifungal drugs. They concluded that this information gives about the several important uses of jackfruit latex or resin, or both can be utilized as the cementing medium, irrigation solution (washing of a body cavity or wound by a stream, denture cleaning solution, resin, and other future dental filling material in terms of cost- effective.

Fast-Dissolving Tablets

The major storage carbohydrate in plants is starch. The annual worldwide production of starch is 66.5 million tons (FAOSTAT 2002) [18]. It has immense industrial use in the manufacture of products such as food, textile, paper, adhesives, and pharmaceuticals. Starch can also serve as a thickening, gelling, and film-forming properties. Jackfruit seed cotyledons are fairly rich in starch and protein. The recent investigation shows that the jackfruit seed starch has potential in pharmaceutical industries. The starch extracted from jackfruit seeds are used as superdisintegrants for the formulation of fast-dissolving tablets (FDT). The FDT technology makes tablets dissolve or disintegrate in the mouth without additional water intake (Debjit *et al.*, 2009) [16]. The basic approach in the development of FDT is the use of superdisintegrants, which provide instantaneous disintegration of tablet after putting on tongue, thereby releasing the drug in saliva. The fast- dissolving tablets are rapidly dissolved or disintegrate by the use of superdisintegrants.

Value-added products prepared by incorporating jackfruit seed flour

Value addition means the modification of a food commodity so as to enhance its value. This can be done by incorporating a new ingredient, using food processing technology or by changing the product packaging resulting in products that are far more appealing and usable. A few examples of value-added products are breakfast cereals, jams, ice-creams, juices, yogurts, cheeses, pickles, concentrates, sauces, ketchup, extruded snacks, etc. Value addition requires creative ideas, a business understanding and market demographics. Jackfruit seeds have been successfully used in the production of certain value-added products, some of which are represented in Table 4 (bakery products), Table 5 (extruded products) and Table 6 (other products).

Bakery products

The bakery industry is amongst the fastest growing organized food industries in India. The chief advantage offered by bakery product is the ease with which they can be fortified with functional ingredients. Therefore, bakery products are an efficacious medium to deliver potent ingredients with health benefits to consumers. Recent studies have indicated that various bakery products such as biscuits (Islam *et al.*, 2015) [25], cookies, bread (Tulyathan *et al.*, 2002) [51], cake (Arpit & John, 2015) [4], muffins (Siti Faridah & Noor Aziah, 2012) [45], etc. have been formulated by supplementation with different levels of jackfruit seed flour (Table 4).

Table 4: Baked products prepared by Jackfruit seed fortification in different forms and at different concentrations.

Product	Amount of Supplementation (%)	Outcome	Reference
Bread	5	High protein and carbohydrate content, good water and oil absorption ability	Tulyathan <i>et al.</i> , (2002) [45]
Bread	25	Increased crude fiber content	Butool & Butool(2015) [10]
Bread	25	Nutritionally higher carbohydrate, fat, protein, and crude fiber content	Hossain(2014) [24]
		Good water and oil absorption capacity,	
Biscuit	20	swelling power, percent solubility, flour dispersibility and viscosity	Butool & Butool (2015) [10]
Biscuit	10-40	Moisture, fat, crude fiber and ash content increased	Islam <i>et al.</i> ,(2015) [25]
Cake	5-15	Increase in protein and reduction in fat content	Arpit & John (2015) [4]
Chocolate cake	5-15	Improved dietary fiber and anti-oxidant activity	David (2016) [14]
Composite cake	10-30	Better crumb, texture and nutritional characteristics	Khan <i>et al.</i> , (2016) [27]
Muffins	10-20	Specific gravity increased and viscosity decreased	Siti Faridah & Noor Aziah (2012) [45]

Extruded products

In many food processing industries, extrusion cooking technology plays a pivotal role as continuous cooking, mixing, shearing and form-making technique, and the main reasons for customer acceptance of extruded foods are the

convenience, value, appearance and texture (Gat and Ananthanarayan, 2015) [20]. This technology is mainly used in the production of breakfast, cereals, snacks, snack pellets, crispy flat bread, pre-cooked flours, and cereal-based baby foods.

Table 5: Extruded products prepared by jackfruit seed fortification in different forms and at different concentrations.

Product	Amount of Supplementation (%)	Outcome	Reference
Expanded snacks	10-40	Increase in nutritional and phytochemical properties	Gat & Ananthanarayan (2015) [20]
Pasta	10	Increased nutrient content	Abraham & Jayamuthunagai (2014) [2]
Fortified noodles	5	Higher protein, fat, fiber, ash content and better organoleptic properties	Nandkule <i>et al.</i> , (2015) [34]
Noodles	10-20	Higher yield ratio and lower cooking time	Kumari & Divakar (2017) [30]

Traditional products

The processed food industry has a continuously increasing interest in developing novel products to attract consumers. Traditional snacks and other products such as Karasev, Jamun, cereal bars, chocolate milkshake and chapatti supplemented with jackfruit seed flour are mentioned in Table 6. Cereal bars made with 30% and 40% jackfruit seed meal showed high fiber contents, better sensory characteristics and nutritive values similar to those of other bars available on the market (Santos *et al.*, 2011) [43]. The development of a cereal

bar with 15% jackfruit seed flour maintained the hardness and crispness when compared with commercially available cereal bars without the addition of this exotic fruit (Torres *et al.*, 2011) [50] and the protein content of the snack bar increased when jackfruit seed flour was incorporated (Meethal *et al.*, 2017) [31]. Jackfruit seed flour, Bengal gram flour, and whole meal wheat flour were blended in different combinations to produce chapatis, the addition of 10% jackfruit seed flour showed the best overall acceptance (Sultana *et al.*, 2014) [47].

Table 6: Other products prepared by jackfruit seed fortification in different forms and at different concentrations

Product	Amount of supplementation (%)	Outcome	Reference
Karasev and Jamun	25 and 50	Decreased fat absorption capacity	Sri Rajarajeshwari & Prakash (1999) [46]
Cereal bar	30 and 40	High fiber content, better sensorial characteristics	Santos <i>et al.</i> , (2011) [43]
Cereal bar	15	Preserved hardness and crispness	Torres <i>et al.</i> (2011) [50]
Snack bar	35-45	Increased protein content	Meethal <i>et al.</i> , (2017) [31]

Recent studies concerning the nutritional properties of three varieties of jackfruit seed flour showed that all the seed varieties contained good amounts of protein, ranging from 13% to 18% and that the crude fiber content varied between 1.56% to 2.60% (Abedin *et al.*, 2012) [1]. Mukprasirt & Sajjaanantakul (2004) [33] reported that the starch obtained from jackfruit seed has a higher amylose content which could be used as a substitute for modified starch.

Various researchers have recognized jackfruit seed as a novel functional ingredient with a desirable nutraceutical potential due to its high content of phytonutrients (Conforti & Cachaper, 2009) [13]. Gupta *et al.*, (2011) [22] found a high amount of saponins i.e., 6.32g/100g on carrying out a phytochemical analysis of jackfruit seeds. The antioxidant activity was determined using free radical scavenging, metal chelating, ferric reducing antioxidant power and reducing power assays, and it was concluded that jackfruit seed exhibited strong antioxidant properties and a moderate amount of phytochemicals. Studies on the total phenolic compounds, flavonoids, reducing power and antioxidant activity of four different extracts of jackfruit seed showed that plants containing phenols and flavonoids exhibit strong antioxidant potentials. These results indicate the use of jackfruit seed extract as a good functional medicine and pharmaceutical plant-based product due to its high flavonoid (0.86 to 4.05) content and reducing potential (9.56 to 13.12) (Shanmugapriya *et al.*, 2011) [44].

The jackfruit seed protein has a high surface viscosity property, so more air is entrapped for a longer time. It has been reported that jackfruit seed flour has low emulsifying capacity when compared to wheat flour.

Future Strategies

- Jackfruit is having tremendous nutraceutical and phytochemical properties.
- Western ghat region is hot spot for variability of both this crops, hence effort should be focused on survey, collection, conservation, evaluation, extraction and quantification of novel bioactive compound of Jackfruit.
- The protocol for development of innovative food products from this crop needs to be developed for commercial exploitation.
- The possibility to use the bioactive compounds in jackfruit in pharmaceutical companies needs as urgent attentions.

Conclusion

There is a need for commercial utilization of the jackfruit can serve as a possible alternative of many vitamins in the body. An activity of certain phytochemicals along with their antioxidant properties further supports the cause of commercial utilization of the fruit. The antioxidant constituents present in the fruits play important role in scavenging free radicals and reactive oxygen species which are responsible for a number of human disorders. The jackfruits and fruit products hold potential in the diet as they possess not only pleasant taste but also source of naturally and readily available source of instant energy.

In Ayurveda the jackfruit is used as a cooling tonic and pectoral, roots in diarrhea and fever, leaves to activate milk in women and animals, as a source to treat antisiphilic and vermifuge, leaf ash applied to ulcers wounds and the warmed leaves have healing properties if pasted on the wounds. The richness of jackfruit in bioactive natural metabolites encourages their consumption. Furthermore, the aqueous extracts activity suggests that it may be useful for food and pharmaceutical industries. The valued jackfruit material, which nowadays is largely discarded by the population, might have an important economic impact for the production.

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