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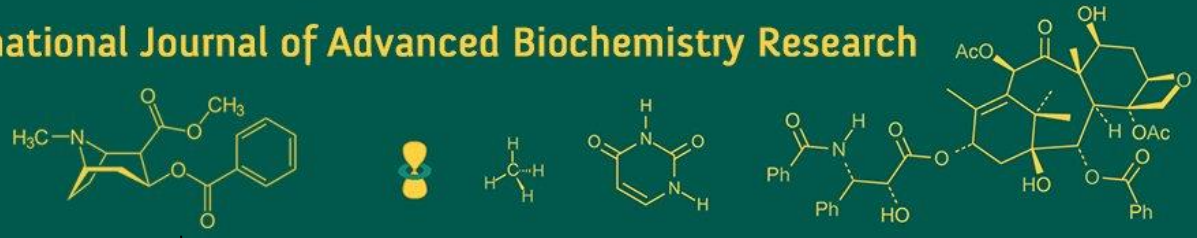

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Gyana Ranjan Mohanty
Department of Genetics and Plant Breeding, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Prasanta Kumar Majhi
Department of Genetics and Plant Breeding, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Subhakanta Samantaray
Department of Agrometeorology, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Monika Ray
Department of Agronomy, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Sandeep Kumar Mallik
Department of Seed Science and Technology, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Abhijeet Swain
Department of Seed Science and Technology, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Ankit Kumar
Department of Genetics and Plant Breeding, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Corresponding Author:
Prasanta Kumar Majhi
Department of Genetics and Plant Breeding, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Flaxseed: The marvel of nature for humanity

Gyana Ranjan Mohanty, Prasanta Kumar Majhi, Subhakanta Samantaray, Monika Ray, Sandeep Kumar Mallik, Abhijeet Swain and Ankit Kumar

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Abstract
Flaxseed or linseed holds the distinction of being one of the first crops domesticated in the old world. Its historical significance and multifaceted utility are well-documented through literary and archaeological evidence, highlighting its longstanding role in food, medicine, and textile fiber production. It is cultivated for its dual-purpose utility in food and fiber production. As an oilseed crop, its primary output is oil, serving commercial purposes. The textiles industry relies on the raw material from flax to produce linen, commonly used in the manufacturing of bed sheets and tablecloths. This composition provides essential information on the cultivation of flax, emphasizing that adopting scientific cultivation technologies is key to achieving better quality and higher production. Exploring its potential as a multi-purpose crop on a global scale, flaxseed is now actively recommended for its role as an immunity booster and nutraceutical. This is particularly significant in a post-COVID pandemic, where the demand for immune-strengthening foods is heightened. Beyond health benefits, flax addresses concerns related to over-reliance on animal-based sources in the human diet linseed boasts a substantial composition of essential fatty acids. In fact, it contains 75% polyunsaturated fatty acids, with 57% of that being alphalinolenic acid an omega-3 fatty acid and 16% being linoleic acid, categorized as an omega-6 fatty acid**.** Furthermore, the incorporation of natural flax fibers in advanced synthetic science and eco-friendly product development positions it as a sustainable alternative. In the current context of climate change and frequent natural disasters, flax emerges as a beacon of hope for fostering sustainable and climate-resilient agriculture.

Keywords: Fatty acid, flaxseed, linoleic acid, oilseed crop, omega-3 fatty acid

Introduction
Flaxseed or linseed (*Linum usitatissimum* L.), a pivotal oilseed crop throughout the history of human civilization, holds significance as a member of the Linaceae family with *Linum* genus. Within this family, comprising 13 genera, *Linum usitatissimum* stands out as the sole cultivated species, distinguished by its diploid chromosome count of 2n=30. Thought to have this species is originated from *Linum angustifolium* Huds native to the Mediterranean region (Gill, 1987) [7]. Linseed has maintained its prominence as an essential and cultivated crop globally which includes diploid species with varying chromosomes (2n=15, 16, 18, 30, 36, 60, 72) (Saroha *et al*., 2022) [24]. The name "*Linum*" has its roots in the Latin word "lin", signifying "thread" while the species name "*usitatissimum*" reflects its status as "most useful". The term "flax" is employed when cultivated for fiber, "linseed" for oil purposes, and "dual-purpose flax" when grown for both oil and fiber (Manimurugan *et al*., 2021) [17]. In various Indian languages, it is known as Alsi, Tisi, Pesi, Pesu, Jawas, Aksebija. Linseed, beyond its role as a crucial oilseed crop, plays a vital part in medicinal practices such as "virechana" a medicated purgation therapy. Historical records reveal that Hippocrates utilized flax in the treatment of abdominal pain, underscoring its enduring significance in medicinal applications (Bernard *et al*., 2014) [2]. Linseed is presently cultivated in several countries and their production (lakh tonnes) includes; Kazakhstan (9.7), Russia (6.08), Canada (4.89), China (3.53), U.S.A. (1.38), India (1.36), Ethiopia (0.88), France (0.46), Afghanistan (0.41), UK and Northern Ireland (0.35). Approximately, 50.4% of the world production share is from the Asian regions. When individual countries are considered, the highest production of linseed was recorded in Kazakhstan followed by Russia.

Rajasthan, Himachal Pradesh, Madhya Pradesh, Maharashtra, Chhattisgarh, Bihar, Jharkhand, Karnataka, Odisha, Uttar Pradesh and Assam are the important Linseed growing states in India (Manimurugan *et al*., 2021) [17].

Flaxseed is well-known for its numerous health benefits, which include supplying a healthy amount of protein and fibres, reducing appetite, and aiding in weight management. Looking to the superior nutrient profile of flaxseeds, it comes as no surprise that flaxseed oil is also loaded with similar health benefits. Almost every part of the linseed plant is beneficial, and it is cultivated because it can be used as both a medicine and a food source. It is possible to consume oil extracted from the seeds and fibre extracted from the stem, both of which are of high quality and very durable (Majhi *et al*., 2023) [16]. In 2014, Health Canada endorsed the claim that taking ground flax effectively lowers blood cholesterol levels (www.healthyflax.org). These small, oval-shaped seeds are recognized for their digestive benefits and their potential to reduce the risk of heart diseases and type-2 diabetes (Kumar *et al*., 2018) [13]. On average, it comprises about 30 to 40% oil, characterized by a rich content of 20 to 25% protein, 20 to 28% total dietary fiber, and essential minerals (Herchi *et al*., 2012) [8]. The seed oil is nutritional superiority is evident in its higher levels of Alpha-Linolenic Acid, an omega-3 fatty acid, Linoleic Acid, an omega-6 fatty acid, and vitamins A, B, D, and E (Morris, 2007) [18]. Flaxseed oil, frequently referred to as flax oil or linseed oil, is produced from flax seeds that have been ground and pressed to extract their natural oil. Flaxseed oil has long been employed as a laxative and for healing wounds. This healthy oil has numerous applications, spanning from cooking to skin care. Flaxseed oil is not heat stable and should not be used as a substitute for vegetable oil in recipes that require heating over heat. The oil can be used in salad preparations and marinades. Before serving, it is also delicious drizzled over grilled vegetables or other cooked dishes. Numerous active compounds in flaxseed oil are believed to provide health benefits, including: i) Alpha-linolenic acid (ALA), an omega-3 fatty acid; ii) Linoleic acid (LA), an omega-6 fatty acid; iii) Oleic acid, an omega-9 fatty acid; iv) Fibre and Lignans, glycosides, and peptides. Flaxseed oil benefits include reducing inflammation, preventing cardiac disease, and promoting digestive health. Flaxseeds have been associated with numerous health benefits, including those related to digestion and a decreased risk of cardiovascular disease, type-2 diabetes and cancer. The antioxidant activity of brown flaxseeds is slightly higher than that of yellow ones. With its high concentration of beneficial nutrients like alpha-linolenic acid (ALA), fibre, protein, and phytoestrogens, it has gained popularity as a healthful food option. About 55% ALA found in flaxseeds, followed by 28-30% protein and 35% fibre (Rabetafika *et al*., 2011; Parikh *et al*., 2019) [22, 21]. Nutritionists and medical experts are becoming interested in flaxseed because of the biologically active components it contains, such as alpha-linolenic acid (ALA), lignan-Secoisolariciresinol diglycoside (SDG), and dietary fibre, and the possible health benefits these compounds may have. This article highlighted about the nutritional and medicinal properties, value added products of flaxseed, advanced industrial uses of linseed and the future direction of works of linseed.

Botanical description of Linseed

Flax cultivars have been selectively bred for distinct purposes, either emphasizing fiber production in the case of fiber flax or prioritizing oil in oilseed flax. Over time, these varieties have diverged in terms of production, climatic adaptation, and morphology. Oilseed-type plants typically exhibit shorter stature, increased branching, and higher seed production, while fiber flax types are generally taller, possess fewer branches, and are specifically chosen for optimal fiber characteristics, including length (4 cm), high tensile strength, and quality cellulose**.** The annual herb is having blue or white flowers and produces small, flat seeds of golden yellow to reddish brown color. The phenology of flaxseed is represented in Figure-1. Flaxseed has a crisp texture and a nutty flavour (Kajla *et al*., 2015) [12]. The superior fibers derived from flax phloem find application in fine textiles and linens, while coarser fibers serve purposes in nonwoven textiles and twine. Both fiber and oil flax varieties share a short tap root system with fibrous branches, with shallow root depth, as only 4–7% extend deeper than 60 cm.

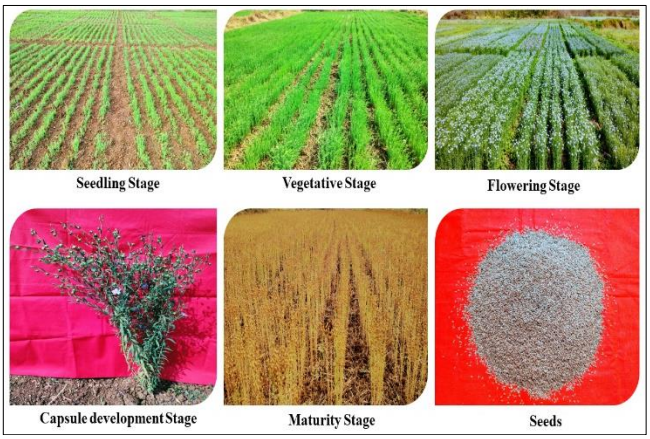

Fig 1: Crop Phenology of Flaxseed

Nutritive Value of Flaxseed

Linseed serves as a remarkable source of essential fatty acids, presenting an alternative omega-3 fatty acid source for vegetarians. With an oil content ranging from 33 to 47%, subject to multiple variables, approximately 20% of the total oil produced in India is utilized by farmers, while the remaining 80% finds application in industries in diverse forms such as boiled oil, borated oil, epoxidized oil, aluminates oil, urethane oil, and isomerized oil. Linseed oil, abundant in alpha-linolenic acid (ALA) at about 55%, also boasts high levels of dietary fiber, lignin, micronutrients, and omega-3 fatty acids. With a pleasing taste, it contains 36% protein, of which 85% is digestible, and serves as a valuable source of minerals, particularly phosphorous (650 mg/100g), magnesium (350-431 mg/100g), and calcium (236-250 mg/100g), with minimal sodium content (27 mg/100g) (Ganvit *et al*., 2018, Morris, 2007, Rabetafika *et al*., 2010, Rubilar *et al*., 2010) [5, 18, 22, 23]. But, The nutritional value of linseed is influenced by various factors, including genetics, growing conditions, biotic and abiotic stresses, and post-harvest processing. Also, Linseed is rich in secondary metabolites, with a notable presence of phenolic compounds renowned for their anticancer and anti-oxidative properties. These phenolic compounds encompass phenolic acids, flavonoids, and lignans. However, linseed also harbors anti-nutritional factors that can potentially impact human health adversely. The primary anti-nutrients in linseed are cyanogenic glycosides, which are further categorized into linustatin (213-352 mg/100g), neolinustatin

(91-203 mg/100g), and linmarin (32 mg/100g) (Oomah *et al*., 1992) [20]. The quantities of these glycosides vary based on factors such as cultivar and location. Notably, linseed employed for fiber purposes tend to exhibit higher glycoside percentages compared to seed types, and the content of glycosides is generally lower in ripe seeds than in immature ones (Singh *et al*., 2011) [26].

Health Benefits of the Flaxseed: Polyunsaturated fatty acids (PUFA) from the omega-3 family, soluble dietary fibres, lignans, proteins, and carbohydrates are only some of the well-known chemical constituents found in flaxseed (Madhusudan, 2009) [14]. However, it contains trace amounts of substances that are harmful to human health, including cadmium, protease inhibitors, and cyanogenic compounds. Flaxseed chemical make-up can change according on its genes, growth conditions, seed processing, and analytical technique. The health advantages of various nutritional compounds of flaxseed are discussed below in Figure-2.

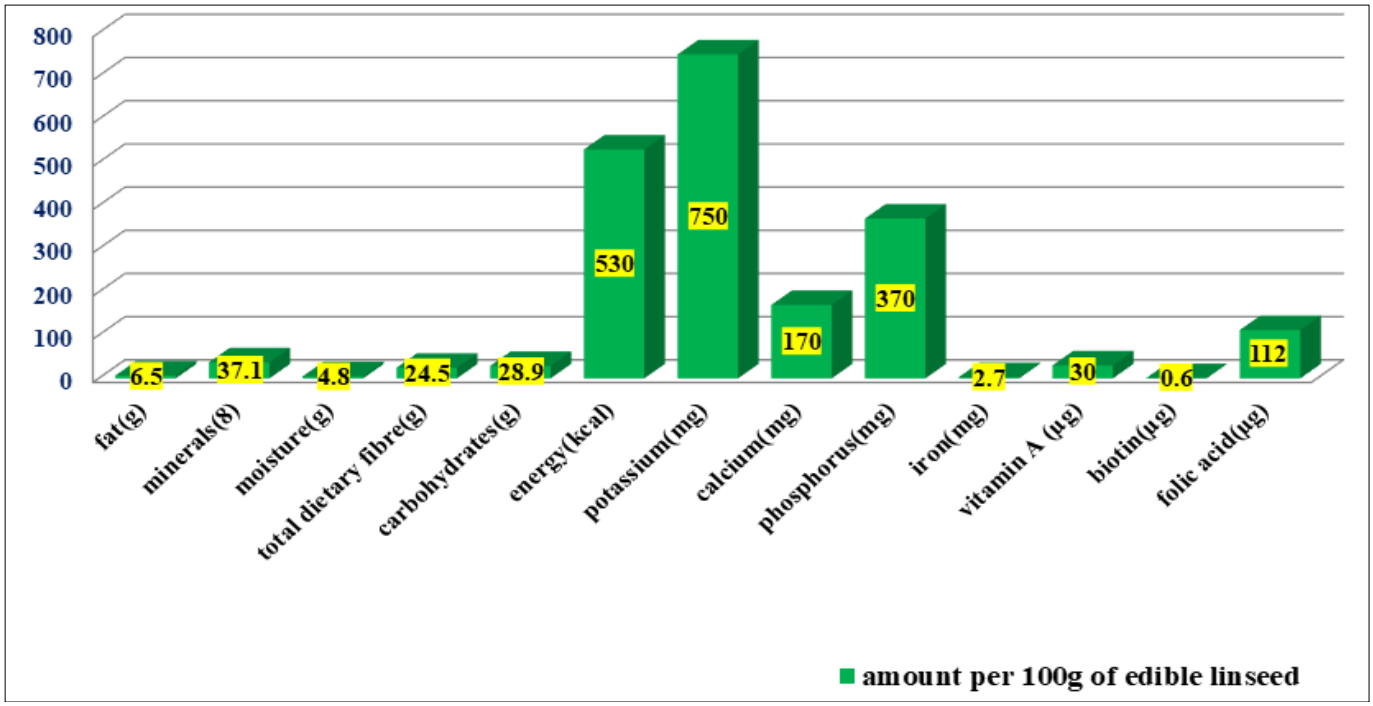

Fig 2: Nutritional profile of Flaxseed

1. Health Benefits of Carbohydrate and Fibre

The carbohydrate content of flaxseeds is 29%, almost all of which is present as fibre. They are low in net digestible carbohydrates (carbs minus fibre) and hence qualify as a low-carbohydrate food. In terms of dietary fibre, two teaspoons (20 g) of flaxseeds contain roughly 6 g. That's about 15-25% of a man's or a woman's RDA (Recommended Daily Allowance). 20-40% of the fibre is mucilage gums, and the remaining 60-80% is insoluble fibre (cellulose and lignin) are present in flaxseed. Blood sugar and cholesterol levels are both aided by consuming soluble fibre. As a bonus, it helps your digestive system by nourishing the good bacteria already there. In the presence of water, the mucilage gums in flaxseeds become extremely thick. As flaxseeds also contain insoluble fibre, they are a healthy alternative to laxatives. Flaxseed consumption has been linked to a lower risk of diabetes, improved bowel regularity, and a lowered likelihood of developing the disease.

2. Health Benefits of Protein

Like other vegetable proteins, flaxseed protein has techno-functional qualities that influence its behaviour in a food system as a result of its interactions with other ingredients. For both solubility and water-oil retention, the hydration mechanisms play a crucial role. Protein derived from flaxseeds shares an amino acid profile with soybeans, a plant protein often considered to be among the healthiest options available. The necessary amino acids are there, but lysine is missing; which means they lack some essential amino acids and are classified as an incomplete protein. Nonetheless, the amino acids arginine and glutamine found in flaxseeds are beneficial to the health of the heart and immune system. Depending on their genetic and environmental backgrounds, flaxseed grain and flaxseed paste can have anywhere from 21 to 34% protein. Typically, seeds grown in cool areas have a high oil content but a low protein level. There are two main types of storage proteins in flaxseed: a salt-soluble fraction with a high molecular weight (11-12S; globulin; 18.6% nitrogen) and a water-soluble basic component with a low molecular weight (1.6-2S; albumin; 17.7% nitrogen). Lysine, Threonine, and Tyrosine are the limiting amino acids in flaxseed, although the ratio of the other essential amino acids is quite favourable. In addition, it contains a healthy amount of branched-chain amino acids and sulphur-containing amino acids (Metionine and Cysteine) (BCAA; Isoleucine, Leucine and Valine).

3. Health Benefits of Fat

About 4 g of fat may be found in every 10 g of flaxseeds, making them a good source of healthy fats. 73% of the fat content is polyunsaturated fatty acids such omega-6 fatty acids and omega-3 fatty acid alpha-linolenic acid (ALA), while the remaining fat content is formed of monounsaturated and saturated fatty acids, making up the

remaining 27%. Because the body is unable to generate ALA, flaxseeds are among the best dietary sources of this crucial fatty acid. Most ALA can be found in flaxseed oil, with ground seeds coming in second. The oil is contained within the fibrous structure of the seed, so consuming the seed in its entirety is the least effective way to obtain ALA (Majhi *et al*., 2023) [16]. The medicinal properties of Flaxseed and human health benefits are described in Figure-3. Flaxseeds, which have a higher proportion of omega-3 fatty acids than many other oil seeds, have a lower omega-6 to omega-3 ratio. One study found that people who consumed fewer omega-6 fatty acids in comparison to omega-3 fatty acids had a lower chance of developing many chronic conditions; while fish oils are rich in omega-3, flaxseeds only a fraction of that amount. Furthermore, ALA in flaxseeds must be converted by the body to EPA and DHA, a process that is typically ineffective. The nutritional value of yellow flaxseed is lower than that of typical brown flaxseed. It's poor in omega-3 fatty acids and has a significantly distinct oil profile.

4. Health Benefits of Minerals and Vitamins

Many nutrients, including vitamins and minerals, can be found in abundance in flaxseeds (Majhi *et al*., 2023) [16].

- **Copper:** Copper is a vital mineral required for normal development and growth as well as other biological processes.
- **Molybdenum:** Molybdenum is abundant in flaxseeds. Seeds, grains, and legumes are all good sources of this vital trace mineral.
- **Phosphorus:** This mineral is important for bone and tissue health and is typically present in protein-rich meals.
- **Thiamine:** Vitamin B1 is another name for this B vitamin. Inappropriate levels can disrupt metabolism and neuronal function.
- **Magnesium:** Magnesium, an essential mineral with numerous physiological roles, is abundant in plant foods like cereals, seeds, nuts, and green leafy vegetables.

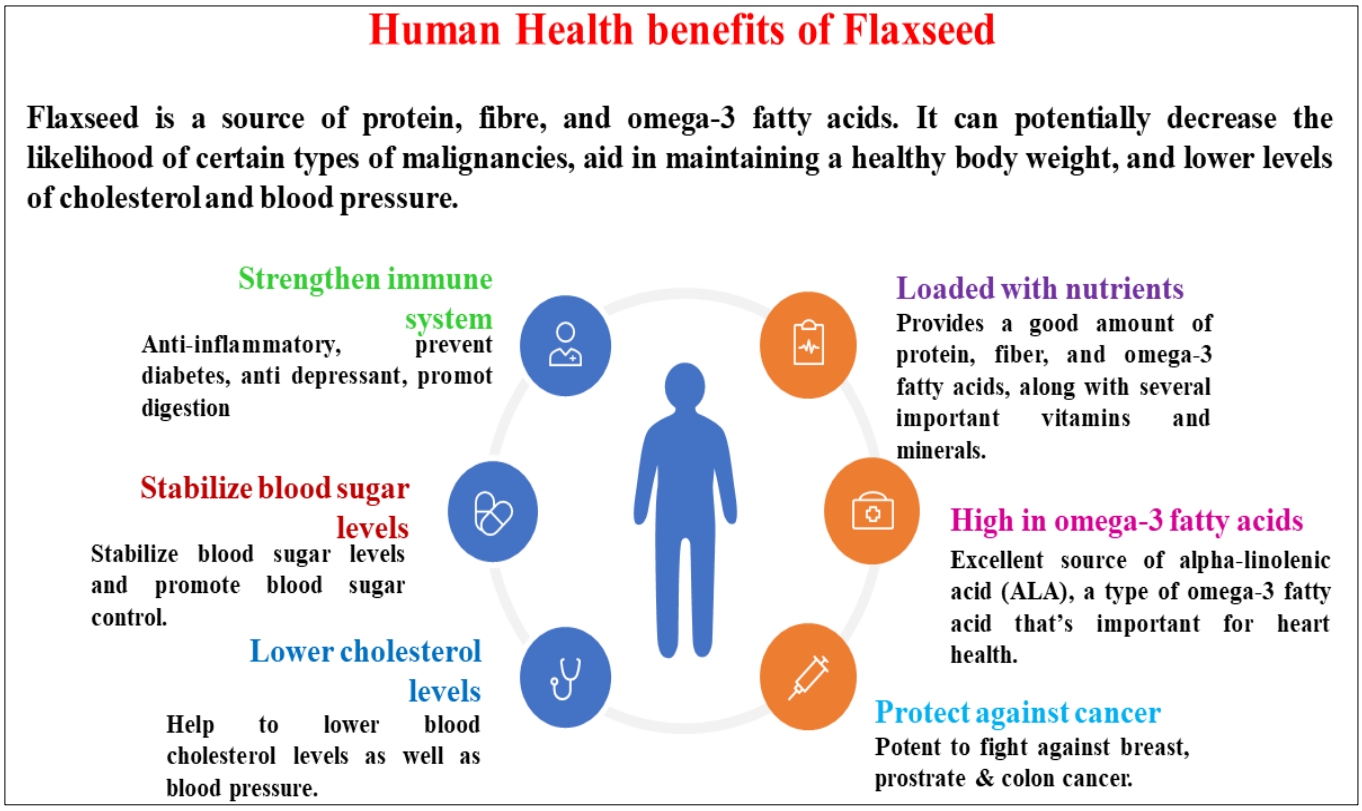

Fig 3: Medicinal properties of Flaxseed and human health benefits

Medicinal Properties of Linseed

Flaxseed oil is a healthier alternative to fish oil for lowering cholesterol levels by supplementing the diet with omega-3 fatty acids. Flaxseed oil enhanced intestinal regularity and stool consistency after four weeks. It has the same efficacy as olive oil and mineral oil, which is saying something. Inflammatory markers, illness severity, blood pressure, and waist circumference were all reduced in a trial of 75 persons with ulcerative colitis, an inflammatory bowel disease (Table-1). Supplementation with flaxseed oil has been demonstrated to considerably raise blood levels of omega-3 fatty acids, which is likely the reason for its health advantages. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are two types of omega-3 fatty acids that have been shown to rise in the body after using flaxseed oil supplements. When it comes to maintaining a healthy heart and warding off heart disease, EPA and DHA are important molecules. Flaxseed oil's principal component is ALA, which the body changes into EPA and DHA. Flaxseed oil and safflower oil, both of which are high in omega-6 fatty acids, were evaluated in a study including 59 participants. Supplementing with 1 tbsp (15 ml) of flaxseed oil daily for 12 weeks resulted in considerably lower blood pressure than safflower oil. In addition, flaxseed oil has been shown to increase arterial flexibility (Majhi and Mohanty, 2023) [15].

Table 1: Medicinal Property and health benefits of Linseed

Sl. No.	Health Benefits	Function
1.	Reduce the risk of cancer	Linseed, which is high in omega-3 fatty acids, may inhibit the development of certain cancers. The lignans inhibit cancer development by stopping the generation of new blood vessels. Regular consumption of flax seeds may reduce the occurrences of breast cancer, which is becoming an increasingly urgent health concern. Lignans offer protection from several forms of cancer since they are a phytoestrogen.
2.	Lower cholesterol levels	Linseed oil is rich in omega-3 fatty acids, which are good for the heart. In fact, there are an astonishing 7,196 mg of omega-3 fatty acids in only one tablespoon (15 ml). In particular, the omega-3 fatty acid alpha-linolenic acid (ALA) found in flaxseed oil is only partially transformed into the active forms (EPA and DHA). It has been shown that omega-3 fatty acids are beneficial to health in many ways, including by lowering inflammation, enhancing heart function, and protecting the brain from the effects of ageing.
3.	Regulate blood pressure levels	Consuming linseeds on a regular basis has the potential to reduce cholesterol and hypertension. Ground linseeds have been shown to reduce diastolic blood pressure. Control type 2 diabetes by balancing insulin and blood sugar.
4.	Reduce inflammation	Linseed ALA and lignans are anti-inflammatory because they prevent the production of pro-inflammatory molecules. Linseed oil has powerful anti-inflammatory effects when consumed regularly. More research is needed to assess the effects of flaxseed oil on inflammation in the general population, as the analysis reveals that it may have varying effects on different people.
5.	Keep your bowel healthy	Constipation, bloating, and other digestive issues including diarrhoea are all alleviated by consuming linseeds. Linseed's fibre helps the body eliminate waste by fueling beneficial microorganisms. In a recent investigation with animals, flaxseed oil was found to be effective as both a laxative and an antidiarrheal agent.
6.	Reduce heart-related risks	Linseeds, thanks to their high Omega-3 content, are a miracle food for people with cardiovascular issues. Consuming linseeds on a regular basis may help alleviate symptoms of blood clotting, as well as prevent stroke, heart disease, pulmonary embolism, and other disorders.
7.	Make skin and hair healthy	Vitamin E, which is abundant in flaxseed oil, helps to stop hair loss and promotes healthy new growth. The anti-oxidant lignans has been linked to better hair and skin health. It has been suggested that flaxseed oil can improve skin health.
8.	Supports healthy weight management	Consuming flaxseeds Fibre-rich foods stimulate the digestive tract, which in turn aids in weight management. Consuming 2-4 tablespoons per day can reduce cravings and stimulate the digestive tract.
9.	Flax seeds are a good source of protein	Daily consumption of flaxseeds will satisfy protein requirements. It has the potential to enhance the health of bones, muscles, cartilage, skin, and hair. Therefore, incorporate flaxseeds into your daily diet to improve your health.
10.	Help ease symptoms of arthritis	Flaxseeds reduce joint pain and rigidity effectively. Despite the need for additional research, people are consuming it in the form of seeds, oil, or capsules to obtain relief.

(*Source*: Manimurugan *et al*., 2021; Nair *et al*., 2021; Majhi and Mohanty, 2023) [17, 19, 15].

This omega-3 fatty acid which is polyunsaturated fatty acid will be converted to docosa hexa einoic acid and eicosa penta einoic acid (EPA and DHA). The DHA and EPA are considered as alternate fish oil / cod liver oil. Most of the oil in flax seeds is alpha linoleic acid (ALA). ALA is an omega-3 that is a precursor to the fatty acids found in salman and other fatty cold water fish (Called EPA and DHA). Linseed is rich in fibre both soluable and insoluble. This fibre is responsible for lowering cholesterol levels in our body. Fibre in the di*et al*so helps to stabilize blood sugar and promotes functioning of the intestines. Flax seed is high in photochemicals. Lignans present in flax promote fertility, reduce peri menopausal symptoms and also helps to reduce breast cancer and type II diabetes (Shakuntala *et al*., 2016) [25]. Omega-3 fatty acids are important in functioning of photoreceptor cells and synapses for synaptogenesis and photoreceptor membrane biogenesis during perinatal period; normal functioning of tissues; and response injury to the nervous system and also during retinal stimulation. One of the omega-3 fatty acids, docosahexaenoic acid is the structural material for nervous tissue, including the brain. It is laid down rapidly in the grey matter of the brain and in the retina of the eye during the first year of life (Innes, 2022) [9]. A linolenic acid is the precursor of docosahexaenoic acid, hence it has been suggested that a daily omega-3 fatty acid intake of 500 mg for infants is necessary to ensure proper cognitive development. Although linseed is produced in many states the food uses are limited, except in north Karnataka and parts of Maharashtra. But, linseed as a food ingredient is not familiar all over despite its large production, due to the lack of awareness. Several value-added products are now a days prepared from flaxseed with immense health benefits (Table-2). There is a need to promote the utilization of linseed in non-traditional linseed areas in day-to-day life owing to its health promoting characteristic (Shakuntala *et al*., 2016) [25].

Table 2: Various value-added products of Flaxseed

Sl. No.	Linseed value added products	Ingredients	Method of Preparation
1.	Salted Linseed	Flax seeds (1cup), salt, water- few drops to dissolve salt.	Dissolve salt into water separately in few drops of water and make a solution. Roast the flax seeds till it attains golden brown. And put off the flame. Pour the salt solution to hot linseed and stir thoroughly. Keep it until the grains get cold. It can be used as a munch for anybody at any age.
2.	Fruit and Linseed Salad	Dice finely, two or three whole fresh juicy fruit per person, peeled if required bananas, kiwis, mangos, pears, pineapples, melons, berries work well – sprinkle with 1-2 dessertspoons Flax	Farm Freshly Ground Linseed Meal and stir; serve immediately, add yoghurt, cream or honey if desired. Yoghurt and Linseed: Stir 1 tbsp Flax Farm Freshly Ground Linseed Meal into a helping of your favorite yoghurt, add fruit or honey to taste.
3.	Linseed and Banana Mash	This makes a hearty sugar-free breakfast, snack or dessert - and it's ultra-filling and it's rich in complex carbohydrates and fibre.	Mash a soft banana with a fork and incorporate 2-3 heaped dessertspoons (20-30g) of Flax Farm Freshly Ground Linseed Meal. Eat immediately
4.	Linseed chutney powder	Linseed (100g), garlic cloves (5), salt, chilli powder, curry leaves (4-5), jeera/cumin seeds (1 tea spoon)	Roast the linseed and add garlic, salt, chilli powder, Jeera, curry leaves and grind finally to powder, serve with roti or hot rice & ghee.
5.	Linseed Holige	Linseed (100 g), jaggery (75 g), maida (100 g), oil (25 ml), water	Prepare dough with maida by adding water and oil. The dough should be soft. Roast the linseed and make into powder. Boil the jaggery on little flame by adding water. Pour the powdered linseed to this syrup. Mix well and make into small balls. Take small quantity of dough and place the linseed balls and close and roll into round shape. Shallow fat fry these holige. And serve hot.
6.	Flax seed ladoo	Linseed (100g), Jaggery (100g), Ghee (20g), dry fruits (10g)	Roast the linseed and grind to coarse powder. Make jiggery into small pieces. Add both powders and mix thoroughly. Add ghee and dry fruits and make into small ladoos. This ladoo is rich in omega-3 and iron content and nutritious.
7.	Linseed fried snacks	Roasted linseed (100g), bason flour (50g), oil (to deep fry). Salt, Chilli powder, ajwan (5g), coriander (20 g), Water (to sprinkle)	Sprinkle water on the roasted linseed, mix salt, chilli and besan flour ajwain and make mixture sprinkle this mixture over roasted water sprinkled linseed and mix thoroughly. After ensuring that the seed are span shed with the mixture deep fat fry these seeds Garnish with coriander and chilli this can be a very tasty snack.
8.	Linseed burfi	Golden flax seed powder or meal (1/2 cup), coarsely ground walnut (1/2 cup), coarsely ground almonds (1/2 cup), coarsely ground cashews (1/2 cup), crushed cardamom (1 tea spoon, about 8 cardamoms), sugar (1 cup), water (1/4 cup)	Roast flax seeds and ground it into powder, mix walnut, almonds and cashew-nuts into a pan and roast, gently, Crush the cardamoms in to powder, Heat sugar and water in a kadai and boil for 15 minutes till the bubbles disappear. Put off the frame and add all the roasted nuts and cardamom powder to sugar syrup and mix well. Pour the mixture to greased plate cut in to required shapes.
9.	Roti fortified with linseed	Jowar flour 1 cup, Water ½ cup, Roasted linseed – 5 gm	Biol the water in a vessel and add salt. Pour this boiling water to jawar flax and stir steadily ensure that no lumps are formed. Mix this with little jowar dry flour and knead make small balls and prepare roti either by rolling pin r by manual method sprinkle roasted linseed over roti and roast the rotis over tava.
10.	Linseed biscuits	100 gm ghee, 100 gm powdered sugar, 200 gm maida, 20 gm linseed, ¼ TSP baking powder. 1tps spoon milk, 1 tsp milk powder, 1 tsp custard cream.	Mix ghee, sugar, milk powder baking, powder and milk and add roasted linseed and Maida, knead well. Make small bulbs and roll them, apply crusted cream, pour roasted linseed over it. Then cut in to biscuit shapes.
11.	Flax seed nutri ladoo	3 - 4 tbsp split Bengal gram, 3 - 4 tbsp broken wheat, 6 - 7 tbsp flax seeds, 3 - 3 ½ tbsp desi ghee, 4 tbsp almond powder, ¼ tbsp cardamom powder, 6 - 7 tbsp powdered sugar, 2 - 3 tbsp jaggery	Firstly, dry roast the Bengal gram, broken wheat and flax seeds in a pan for 8-10 mins. Meanwhile, mix desi ghee, almond powder. cardamom powder and powdered sugar in a bowl. After this, grind the roasted mixture and mix it in the prepared powdered mixture. Now mix jaggery in it and shape them. Next, coat the ladoos in the roasted flax seeds. Garnish the prepared ladoos with cardamom powder. Your Flax Seed Ladoos are ready.
12.	Linseed chikki	Roasted linseed ½ cup, Roasted ground nut 1 cup, Jaggery – 1 cup, Ghee – To smear to plate water – ¼ cup	Boil the jiggery with water till the jiggery syrup is formed. The syrup should and pour the roasted linseed and groundnut to the syrup. Mix well and pour this mixture to greased plate with ghee then spread evenly. The chikki evenly when it is still warm cool and store in plastic covers. Chikki is a nutritious food for all kind of people.
13.	Salted Linseed biscuits	100g ghee, 200 gm Maida, 20g linseed, 1 teaspoon baking powder, 1 tea spoon, milk powder, ½ tea spoon soda, 1 teaspoon vanilla, Milk as required to knead salt – to tase chili paste to taste.	mix ghee, baking powder, salt, milk powder, powdered jeera, chilli, with maida and knead the roughly. Then prepare small balls of kneaded dough roll them and apply custard cream and linseed. Then cut in to required shape and bake@1800C till the biscuits turn brown.
14.	Linseed puffed rice ladoo	Puffed Rice (4 cups), Jaggery (1 ½ cup), Roasted linseed (1/2 cup), Water (1/4 cup)	Heat the sugar and water, till the bubbles disappear. Then cool the syrup, add puffed rice and make into round ladoo. Roll these ladoo in to roasted linseed and serve.

***Source*:** Manimurugan *et al*., 2021; Nair *et al*., 2021) [17, 19].

Traditional uses of flaxseed

Flaxseed oil possesses a dual nature, serving both edible and non-edible purposes. In the realm of edibility, it proves valuable as a dietary supplement, seamlessly integrating into Mediterranean diets and fireless cooking practices. Its versatility extends to salad dressings, dips, smoothies, and shakes. Beyond the culinary realm, this oil finds applications in cosmetics and personal care products, including moisturizers and hair masks. However, its high alpha-linolenic acid content makes it less suitable for direct cooking. On the non-edible front, approximately 80% of total flaxseed oil production caters to industrial needs. It takes diverse forms such as boiled oil, borated oil, epoxidized oil, aluminated oil, urethane oil, and isomerized oil. Its significance transcends into the production of alkyd paints, renowned for their air-induced drying and hardening properties (Juita *et al*., 2012) [11]. Additionally, the industrial-grade oil contributes to the formulation of oil cloth, varnish, ink, linoleum, and more. Notably, crude linseed oil exhibits moderate insect repellent properties. In the agricultural domain, linseed oil cake, a by-product of solvent extraction, stands out as a nutritionally superior feed source for milch cattle and poultry when compared to rapeseed-mustard cake. Beyond its nutritional value, flax fibers emerge as exceptional materials, combining softness, shine, strength, and durability. The highest quality linseed fiber is highly sought after for Damask Linen-like tablecloths, table runners, dining napkins, and lace production.

Advanced uses of Flaxseed

Horticultural Use

Linseed finds a crucial role in horticulture due to its rich composition of essential nutrients and compounds. As a natural source of omega-3 fatty acids, linseed contributes to soil fertility, promoting the growth of healthy plants. Its oil, extracted from the seeds, is a valuable organic fertilizer, enhancing soil structure and moisture retention. Moreover, linseed serves as a beneficial companion plant, deterring certain pests and diseases. Its allelopathic properties inhibit the growth of weeds, offering a natural and sustainable method of weed control in agricultural settings. The cultivation of linseed alongside other crops, known as intercropping, showcases its potential to foster biodiversity and minimize the need for synthetic pesticides.

Renewable Energy

The linseed plant plays a crucial role in the realm of renewable energy, primarily through the extraction of linseed oil. Linseed oil serves as a feedstock for biodiesel production, contributing to the development of sustainable alternatives to conventional fossil fuels. The biodiesel derived from linseed oil is environmentally friendly, emitting fewer greenhouse gases compared to traditional diesel fuels. Additionally, linseed's residual biomass, such as stalks and husks, can be utilized for bioenergy production. Through processes like anaerobic digestion or combustion, these by-products can be converted into biogas or used as a source of thermal energy, further emphasizing linseed's potential as a renewable energy resource.

Paper Industry

In the paper industry, linseed plays a vital role as a source of fibers for paper production. The bast fibers obtained from the stem of the linseed plant are long and durable, making them ideal for high-quality paper products. These fibers contribute to the manufacturing of fine-grade papers, including specialty papers used in art and printing. The use of linseed fibers in paper production aligns with sustainable practices, as flax cultivation requires fewer pesticides and synthetic fertilizers compared to some other fiber crops. The paper industry's adoption of linseed fibers supports eco-friendly initiatives and reinforces the shift towards more sustainable raw materials.

Phyto-Remediation

Linseed exhibits notable potential in phyto-remediation, a process where plants are employed to mitigate environmental pollution. The plant's extensive root system and ability to accumulate heavy metals make it suitable for rehabilitating contaminated soils. Linseed's capacity to absorb and store pollutants such as lead and cadmium can be harnessed to remediate areas affected by industrial activities or improper waste disposal. Furthermore, the cultivation of linseed in phytoremediation projects contributes to soil conservation, preventing erosion and promoting overall ecosystem health. This application underscores linseed's dual role as both a commercially valuable crop and an agent of environmental restoration. The research findings suggest that linseed exhibits a cadmium (Cd) exclusion trait in its roots, concurrently displaying hyper-accumulation tendencies for lead (Pb) and zinc (Zn) in above-ground tissues. The plant employs a combination of phytostabilization and phytoextraction mechanisms to achieve these contrasting behaviors (Drozlowska *et al*., 2020) [4].

Use in composite of polymer

Flax fiber reinforced polymer (FRP) composites have emerged as a significant asset in automotive design, with leading automobile brands actively testing these composites in various components such as interior panels, visors, and rear shelves. This innovative application showcases the potential for lightweight and durable materials to enhance the overall performance and sustainability of vehicles in the automotive industry (Berglund, 2002) [1]. The utilization of Linseed Fiber Reinforced Polymer (FRP) in vehicle components holds immense potential, particularly in the design of vehicles intended for outer space and deep-sea missions, where these FRP-based components can serve as effective crushable energy absorbers. This innovative application demonstrates the adaptability of such materials to meet the unique challenges posed by extreme environments, paving the way for enhanced safety and performance in aerospace and deep-sea exploration (Yan *et al*., 2017) [28].

Geotextiles

In the realm of insulation, geotextiles play a pivotal role. Through the blending and processing of coarse and fine flax fibers, insulation batts are crafted these batts involve wadding fibers into sheets. Remarkably, these geotextile insulation batts exhibit insulation properties akin to traditional fiberglass batts, serving as an effective solution for insulating walls and ceilings (Jacobsz and Vander Merwe, 2012) [10]. As we continue to explore innovative solutions, linseed stands as a testament to nature's ability to offer multifaceted benefits for a more sustainable future.

Progress with innovative approaches and advanced strategies

The primary focus in the upcoming days should be to enhance linseed's revenue for farmers, fostering increased acreage and production, with a crucial link to diversifying its applications and elevating demand (Dash *et al*., 2017) [3]. To achieve this objective, stakeholders at all levels, spanning production, supply chain, and consumption, must be considered and the strength, weakness, opportunity and threat (SWOT) of linseed research must be taken into consideration (Figure-4). Leveraging brands and NGOs like FabIndia and Navdanya, proponents of the Organic movement, can aid in popularizing and marketing flax and its derivatives (Singh *et al*., 2018) [27]. Implementing a targeted crop improvement program is essential, along with efforts to enrich and extract specific phytochemical constituents from linseed. Utilizing modern plant breeding approaches, such as Gaurav, Sikha, Jeewan, Him Alsi-2, and Jawahar-7, requires increased adoption through awareness campaigns. Traditional breeding approaches addressing higher yield and stress resistance remain relevant for resilient climate agriculture. Incorporating biotechnological methods like ODM, Intragenesis, RNA interference, and CRISPR-Cas9 can expedite and enhance research. A significant obstacle in diversifying linseed applications arises from the lack of linkage between stem and seed maturation in most varieties, adversely affecting quality (Zuk *et al*., 2015) [29]. Addressing this issue is crucial for utilizing flax as both fibre and oilseed without compromising quality. Therefore, incorporating temporal synchronization of fibre and seed maturity in crop phenotype modeling studies is imperative. Further research should explore linseed's potential for phyto-remediation, alongside designing flax composites for innovative functions, particularly in the technical textiles sector.

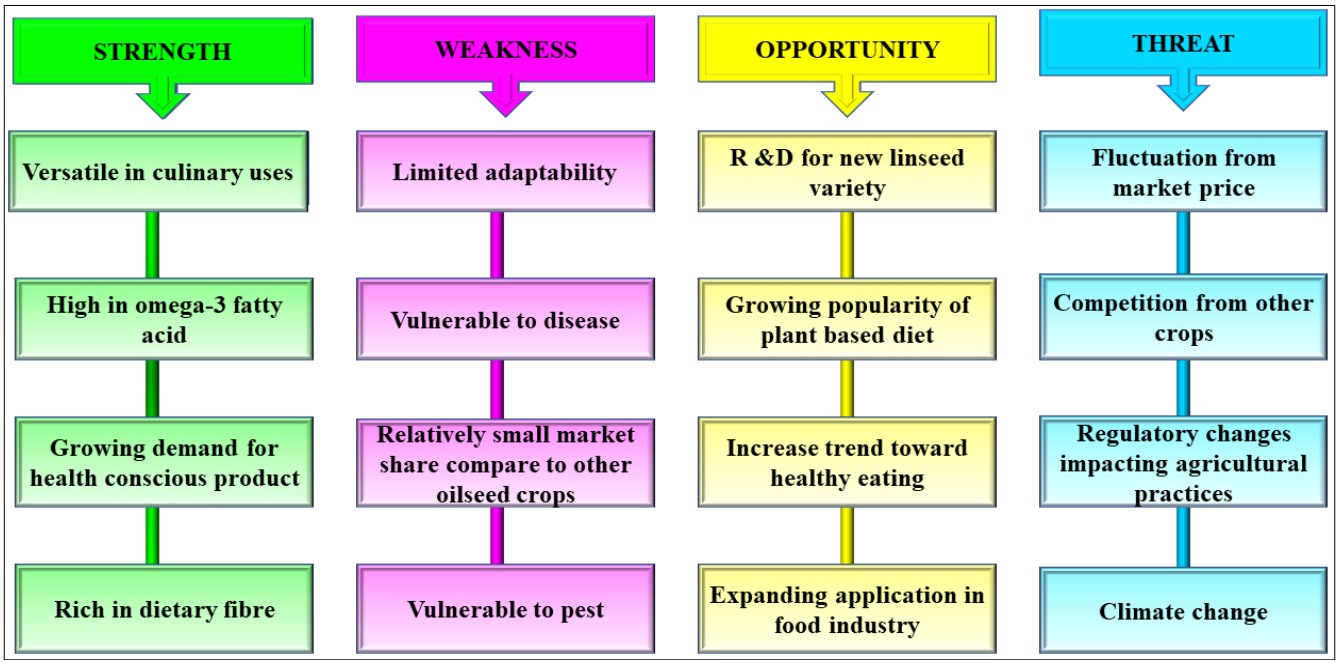

Fig 4: Strength, weakness, opportunity and threat (SWOT) analysis in Linseed research

Conclusion and Future Direction

Linseed is known for its impressive nutritional profile, which consistently fascinates health lovers. Linseed is rich in omega-3 fatty acids, fibre, and lignans, which together promote cardiovascular health, aid in digestion, and give powerful antioxidants. In addition to its widely recognised characteristics, current research is investigating the potential anti-inflammatory properties and the effects on hormonal equilibrium. Moreover, the culinary flexibility of linseed, whether integrated into regular meals or used in the concentrated form of flaxseed oil, highlights its capacity to promote both nutrition and well-being. Linseed, a long-standing dietary staple, continues to be an appealing option for anyone looking for a natural and comprehensive approach to health. Linseed is a versatile plant that requires minimal upkeep and has many qualities that enhance the immune system. Utilising flax fibre not only has scientific importance but also offers chances to boost our economy through job creation and revenue generation. Amidst the prevailing issues of micro-plastic pollution and climate change, linseed has emerged as a promising remedy, gaining its nickname as the "Golden Elixir" for its ability to revive vegetation on our planet. Linseed oil contains omega-3 fatty acids, which have been associated with several health advantages. These include regulating blood sugar levels in those with type 2 diabetes, lowering the likelihood of breast cancer, and decreasing the occurrence of cardiovascular issues. Although these findings are promising, further investigation is necessary to determine their applicability to the human population. Further experimentation on humans is necessary to determine its efficacy in promoting cardiovascular health. Flaxseed does not provide a sufficient amount of these nutrients to have any discernible physiological effects on the body. The utilisation of advanced plant breeding methods and state-of-the-art food processing processes can effectively enhance the biochemical components of flaxseed to meet future demands. The nutritional value of flaxseed is unmatched when compared to any other seed. Flaxseed is rich in omega-3 fatty acid alpha linolenic acid, lignan secoisolariciresinol diglucoside (SDG), and fibre. These compounds possess anti-inflammatory, anti-oxidative, and

lipid regulating properties, which contribute to their usefulness in promoting animal and human health. The four most common types of flaxseed used for human consumption are whole flaxseed, ground flaxseed, flaxseed oil, and partially defatted flaxseed meal. Flaxseed contains several advantageous chemicals, such as protease inhibitors, phytic acids, linatine, and cyanogenic glycosides. However, studies conducted on humans have not found any adverse effects resulting from the use of these compounds. The quantities of these constituents supplied by flaxseed in the diet may be inadequate to trigger any physiological reactions. However, it is prudent to take into account the expressed worry. Plant breeding or food processing can reduce the quantities of these components in flaxseed.

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