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DEVELOPMENT POTENTIAL OF *ERAGROSTIS TEF* AS A FLOUR ALTERNTIVE

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ABSTRACT

Teff (*Eragrostis tef*) *is* known as a health functional food and has been gaining its popularity across the world. Teff is a staple crop and has been cultivated for thousands of years in Ethiopia and Eritrea, currently producing 90% of the world's teff. As the number of consumers are increasing, who look for an alternative to wheat flour especially for people with celiac disease, more countries are increasing teff production. People at all ages can benefit from consuming teff as it contains dietary fiber, iron, potassium, and *etc*. It is also helpful for people with obesity and diabetes due to its low glycemic index. Therefore, modern society pursues health-oriented thinking, and teff is expected to be in the spotlight as a good food for all ages to consume. However, information on the nutritional benefits of teff and research on food development using teff are insufficient. This review paper is a literature review, and the method is a narrative review. In addition, it is suggested that the frequency of Teff intake can be increased by presenting the introduction of foods with high nutritional value using Teff by providing basic data on nutrition and efficacy through a close investigation of Teff.

1. Introduction

Teff (*Eragrostis tef*) is an annual plant in the rice family (D'Andrea, 2008) and is a kind of grain. Chloridoideae and teff's Eragrostoidae are synonymous and similar (Costanza *et al*., 1999). The word teff is derived from the Amharic word teffa, which means "lost", is elliptical and has a particle size of 1 mm or less within 2 mm (Belay *et al*., 2009; Bultosa, 2007). Teff is a tropical cereal originating in the highlands of northern Ethiopia (Tadesse, 1993). Since the beginning of Ethiopia, it has been cultivated for thousands of years. In Ethiopia, Eritrea, South Africa, the United States, Australia, India, Canada, Switzerland, the Netherlands, Europe and North America, 200 million people around the world are cultivated and produced (Costanza *et al*., 1979; Zhu, 2018; Assefa *et al*., 2015; Shumoy and Raes, 2016). There are white, red, and brown types of teff, and foods made with white teff are preferred, but health-conscious people prefer brown teff and the consumption is increasing (Gebremariam *et al*., 2012; Cherie *et al*., 2018). Especially in Ethiopia, more than 30 million people consume teff every day (Nascimento *et al*., 2018), and in Europe and North America, it is steadily consumed (Shumoy and Raes, 2016). In addition, teff is an important nutrient source for people as a food with the potential to grow anywhere in the world and a good source of thiamine. Gluten-free foods include rice, soybeans, corn, millet, buckwheat, tapioca, amaranth and cassava (Awulachew, 2020; Niro *et al*., 2019). Teff is an important nutrient source for people. Teff is a health food containing protein, fiber, crude fiber, polyphenols, and unsaturated fatty acids. It has higher amino acid content than other grains such

as wheat, rice, and corn (Spaenij-Dekking *et al*., 2005; Gebru *et al*., 2019; Hager *et al*., 2012; Abebe *et al*., 2015). It is richer in dietary fiber, minerals, magnesium iron, folic acid, zinc, manganese, phosphorus, calcium, and copper than wheat, barley, and sorghum (Zhu, 2018; Mengesha, 1966; Abebe *et al*., 2007; Post *et al*., 2012; Campo *et al*., 2016). It also contains 8 essential amino acids (leucine, lysine, methionine, valine, isoleucine, threonine, tryptophan, phenylalanine) and (Hager *et al*., 2012) tannin and other polyphenols, which are derivatives of flavonoids, proven to be an important source of physiological activity (Shumoy and Raes, 2016; Urga *et al*., 1997; Ravisankar *et al*., 2018). According to a recent study, it is said that K, P, Ca, Mg, Na, B, AI, and Fe are the most abundant, and Er, Eu, and Sb are also detected in trace amounts (Dame, 2020). Because of its low GI index, Teff can be preferred as an diabetic diet as a non-pharmacological treatment for patients with diabetes to manage their blood sugar level (Gebru *et al*., 2020). In particular, teff contains a significant amount of phenolic, which is beneficial for cardiovascular disease and cancer prevention due to its antioxidant activity (Dykes and Rooney, 2007; Awika and Ronney, 2004), and can reduce the digestibility of food by inhibiting digestive enzymes while acting as a natural antioxidant (Maheshu *et al*., 2013; Qiang *et al*., 2006). Iron can be taken as a supplement or fortifying agent, but certain side effects can cause nausea, constipation, and diarrhea, so it is safer to consume it as a natural grain (Kassebaum *et al*., 2014; McLean *et al*., 2009). In progress, research is being conducted on various foods such as making food by using teff with fenugreek, oats, okara, and rice, or adding kimchi and lupine to Injera dough. In addition, teff can be considered to be excellent as a feed source for animals due to its good health function and quality (Legessea *et al*., 2020; Leykun *et al*., 2020; Minarovičová *et al*., 2019; Gebru and Sbhatu, 2020, Yegrem *et al*., 2021; Kakabouki *et al*., 2020; Hawa *et al*., 2018).

As the world enters an aging society, the health care industry is now thriving, and the importance of healthy food has become the center of interest among people today. Therefore, in this study, teff, which is excellent in terms of its physiological benefits to individual's health, is considered an alternative to wheat flour, and it is believed that it can successfully meet consumers' needs. This study will provide basic data of the nutrition and efficacy of teff, and consequently discuss the importance of teff consumption for individuals.

2. Ethiopia with teff as a staple

Anemia refers to a condition in which the ability to transport oxygen in the body is reduced due to a decrease in the number of red blood cells in the blood and an insufficient content of hemoglobin. A number of people in developing countries are diagnosed with anemia, accounting for 25% of the world's population (McLean *et al*., 2009). Iron deficiency is a common problem not only in low-income countries, but also in developed countries, and it can cause developmental problems for babies and children. Thus, it is especially important for growing children and premenopausal women to consume iron.

One study found that the iron content of wh eat bread containing 30% teff increased twice ir on intake. As a result, the basic iron content that pregnant women need to consume can be maintained with bread containing 30% teff (Kassebaum *et al*., 2014). In another study found that Ethiopian sportsmen around the world are known to have good physical strength. Ethiopia produced a number of marathon winners, because their traditional food called injera is rich in iron, which help to deliver more oxygen by increasing hemoglobin levels (Andrews *et al*., 1990). Teff powder is the main ingredient of injera and is fermented with water to make it round and thin to form a pancake-like shape (Fischer et al., 2014). It is eaten a lot as a staple food and served with most meals in Ethiopia (Urga *et al*., 1997).

3. Nutritional problems of gluten

Teff was previously a kind of grain that was not widely known, but as its nutrition and efficacy are gradually known, it is in the limelight by consumers and is establishing itself as a superfood (Spaenij-Dekking *et al*., 2005, Zhang *et al*., 2016). Teff is a healthy alternative for people with gluten intolerance. Gluten, a protein present in wheat, barley, and rye, is a problem of permanent intolerance causing inflammation to the microvilli in the lining of the small intestine, mucous membranes and gastrointestinal tract, which results in limiting the absorption of nutrients. Accordingly, the lack of nutrients affects skin diseases, anemia, osteoporosis, and growth inhibition, and is linked to diseases such as infertility and small intestine cancer. This is called celiac disease and is a disease of the digestive system and allergies (Green and Cellier, 2007; Green *et al*., 2005; Gil-Humanes *et al*., 2014; Laureati *et al*., 2012; Susanna and Prabhasankar, 2013; Heo *et al*., 2013; Lebwohl *et al*., 2018). About 1% of the world's population, including both young children and adults, complained of difficulty with tolerating diet with gluten (Gujral *et al*., 2012; Aguilar *et al*., 2016; Blanco *et al*., 2011; Bourekoua *et al*., 2018; Turkut *et al*., 2016) and only about 1-2% of the population in Europe was found to have gluten intolerance (Allen and Orfila, 2018). People with celiac disease must adhere to a strict diet with gluten-free products and flour substitutes for effective treatment. In particular, the Western-style diet has a lot of flour-based food and bread is a staple food, so it is difficult to choose food because there are many restrictions. In addition, People with celiac disease are deficient in vitamin B12, iron, zinc, copper, and minerals, so food choices are important, and the choices are limited (Bascuñan *et al*., 2017; Barera *et al*., 2004). In order to solve this problem, it is considered that more attention and research on food such as teff and food development research using it are needed.

4. Gluten-free food research using teff

In the study for patients with celiac disease, it was found that a diet using Teff was effective. Researches using teff are being conducted, including bread, cookies, soup, raw noodles, pasta, beer etc (Bultosa, 2007; Gebremariam *et al*., 2012; Zhang *et al*., 2016; Green *et al*., 2005, Hopman *et al*., 2008; Ronda *et al*., 2015; Hager *et al*., 2012).

A study by Blanco *et al*. (2011) found that gluten-free bread with teff added was increased in carbohydrates, fiber, essential amino acids, iron, calcium, copper and zinc. In another study, teff is considered to have a slow aging rate, and in Korea, where rice is consumed as a staple food, it is considered to be good for use in porridge, rice cake, and rice (Campo *et al*., 2016; Bultosa *et al*., 2002; Joung *et al*., 2017). Therefore, since there are various foods made using rice, it is considered good to make *Gangjeong* and *Dasik*, including rice cake, a traditional Korean food. In addition, it is considered to be good to add to side dishes or use as a garnish instead of sesame seeds. As the number of consumers seeking health orientation increases every year, the need for research on the development of food containing teff, a flour substitute, becomes important, and it is judged as a material that has the potential to help many people. In particular, gluten intolerance and health-conscious people, including celiac disease patients who have to consume gluten-free food and have to follow a diet, are encouraged to actively use Teff for their health. Consumption of health foods, superfoods, wellness foods, and gluten-free foods is rapidly increasing because people's interest and desire for a healthy life are increasing day by day as the lifespan of humans is prolonged. Accordingly, it is necessary to study the development of products with improved functionality and taste, and it is considered that cooks, nutritionists, and researchers must continuously conduct research to contribute to a healthy human life.

In 1941, in a report by pediatrician and scientist Willem Karel Dicke, the onset of a gluten-free diet became increasingly known to consumers over time (van Berge-Henegouwen and Mulder, 1993). In the U.S., sales of gluten-free products rose by 6% in 2015-2016, and the global market is projected to increase

significantly from $5.6 billion to $8.3 billion in 2020-2025 (Statista). As a result of these statistics, the number of consumers choosing gluten-free foods is increasing, and it can be seen that not only patients with celiac disease but also those with poor digestibility for flour foods are increasing. Among the gluten-free products, it was found that the demand for bread was higher than that of other products (Encina-Zelada *et al*., 2018), and the researchers studied gluten-free breads and muffins using various grains including teff, such as buckwheat, sorghum, rice, and amaranth. Bread research is more active than other products, and studies on gluten-free foods using amaranth, quinoa, buckwheat, potato starch, sorghum, rice corn flour, green corn, green banana flour, legumes, and lupines are in progress. It was thought that the improved gluten-free foods and flour-based foods on the market should also be continuously developed and researched (Palavecino *et al*., 2014; de la Barca *et al*., 2010; Ferreira *et al*., 2016; Camelo-Méndez *et al*., 2018; Foschia *et al*., 2017; Zandonadi *et al*., 2012; Gambuś *et al*., 2009; Altındağ *et al*., 2015; Rodrigues Ferreira *et al*., 2009; Foschia *et al*., 2017; Alvarez *et al*., 2017; Lamacchia *et al*., 2014; Collar *et al*., 2014).

5. Problems with side effects and complications from celiac disease

Celiac disease is also said to be a genetic and non-hereditary disease, but it is closely related to wheat. In Korea, rice is a staple food, but the intake of wheat flour is increasing every year due to the prevalence of Western-style diet, and as a result, the possibility of celiac disease, gluten allergy, and skin diseases are increasing (Ministry of Food and Drug Safety 2011). Celiac disease has symptoms such as diarrhea, recurrent abdominal pain, fatty stool, chronic fatigue, weight loss and nutrient absorption disorders, gastrointestinal symptoms, aphthous stomatitis, decreased bone density, and short stature (Kelly *et al*., 2015; Reilly *et al* ., 2011). Complications of celiac disease include hyposplenic syndrome, RCD, intestinal lymphoma, small intestine adenocarcinoma, and jejunoileitis. In addition, celiac disease is associated with intestinal-brain axis and inflammatory states and migraines, and can cause a variety of neurological conditions; seizures including epilepsy, cerebellar ataxia and chronic neuropathy (peripheral neuropathy), myoclonic ataxia, progressive leukemia and dementia. With this complication, neurological symptoms can occur both in children and adults with celiac disease (Cooke and Smith, 1966, Hadjivassiliou *et al*., 2002; Zelnik *et al*., 2004; Arzani *et al*., 2020). Diseases related to celiac disease include autoimmune type 1 diabetes, Hashimoto's thyroiditis, Graves' disease, autoimmune hepatitis, primary biliary cholangitis, primary sclerosing cholangitis, herpes dermatitis, vitiligo, Addison's disease, alopecia, psoriasis, IgA deficiency. And Autoimmune atrophic gastritis, autoimmune hemolytic anemia, Sjogren's syndrome, scleroderma, systemic lupus erythematosus, polymyositis, rheumatoid arthritis, myasthenia gravis, and IgA nephropathy (Burger's disease). Idiopathies include dilated cardiomyopathy, epilepsy with or without laryngeal calcification, cerebellar ataxia, peripheral neurosis, multiple myoclonic seizures, multiple sclerosis, cerebral atrophy, chronic inflammatory bowel disease, sarcoidosis, and atopy. The chromosomes include Down syndrome, Turner syndrome, and Walliam syndrome. If you continue to have complain of symptoms of abdominal pain, diarrhea, intestinal obstruction, fever, weight loss, and severe asthenia even after eating a gluten-free diet, you should be suspected of complications. After age 50, the late diagnosis of celiac disease and failure to follow a strict gluten-free diet will result in mortality. It can be high (Caio *et al*., 2019; Al-Toma *et al*., 2006; Rubio-Tapia *et al*., 2016). A recent study found a high prevalence of celiac disease in patients with Wilson's disease (Drastich *et al*., 2012), and it was also found to be associated with type 1 diabetes (Marchese *et al*., 2013). In addition, studies have shown that the more gluten-containing flour foods consumed during the first five years of life, the higher the risk of immune and celiac disease in children with genetic celiac

disease (Aronsson *et al*., 2019). When celiac disease cannot absorb various nutrients including calcium, it is directly related to growth problems in children and adolescents, so care should be taken. In the elderly, it can be said to be a serious problem due to a decrease in bone density and an increase in the risk of fracture (Mautalen *et al*., 1997; Motta *et al*., 2009; Vasquez *et al*., 2000). Therefore, celiac disease is a problem of malabsorption, which is a major problem of nutritional deficiency and calcium deficiency. Since this factor affects later bone changes, the association between bone mineral density, osteoporosis and fracture should always be considered when diagnosing celiac disease. In celiac disease, calcium intake is a very important nutrient for treatment, so it is recommended to consume it on a gluten-free diet that is high in calcium, phosphorus, and magnesium (Sdepanian *et al*., 2003). A gluten-free diet could have clinical benefits for women with autoimmune thyroid disease (Krysiak *et al*., 2018; Lundin and Wijmenga, 2015), and pain was improved after a gluten-free diet for 6 months and 12 months in patients with endometriosis and chronic pelvic pain (Marziali *et al*., 2012; Marziali and Capozzolo; 2015). It is emphasized that there is a need for continuous research on gluten-free foods, and efforts to improve foods with enhanced nutrients and quality through scrutiny of existing gluten-free products (Kulai and Rashid, 2014; Berti *et al*., 2004).

6. Health benefits of teff as a flour alternative

The biggest advantage of teff is that it is gluten-free, so it can be used as a flour substitute for people especially for those who suffering from celiac disease, and its high iron content is a good ingredient for children and pregnant women (Hopman *et al*., 2008; Cerami, 2017).

The number of diabetes patients around the world has been significantly increasing every year (Danaei *et al*., 2011). As a result of a survey of people aged 20 to 79 in 2021, the global prevalence of diabetes was 10.5% (536.6 million), and the global diabetes-related medical expenditure was $966 billion in 2021. It is expected to increase by 12.2% (783.2 million people) in 2045, and is estimated to be $1.54 trillion in 2045 (Sun *et al*., 2022). It is also estimated that 1 in 9 people between the ages of 20 and 79 with diabetes will die, with those under 60 having the highest number of deaths, with an estimated 4.2 million deaths (Saeedi *et al*., 2020).

Diabetes is a metabolic disorder in which blood sugar levels increase whereas the body does not produce enough insulin to use glucose from blood for energy. Causes include high fat diet leading to obesity, sedentary lifestyle, and decreased exercise capacity. In addition, it was found that obesity and diabetes incidence were increasing due to excessive consumption of fat and sugar in diet and lifestyle-related diseases (Guariguata *et al*., 2014). Therefore, for diabetics, the amount and quality of carbohydrates, the level of glucose, and the response of cells to insulin are the main points, which is a part that requires a lot of attention when ingesting carbohydrates (Wolever, 2000).

One study found that low-glycemic foods could reduce the risk of type 2 diabetes, and that, unlike other grains, teff with a low GI index could play a major role in diabetes prevention (Augustin *et al*., 2015; Wolter *et al*., 2013). Compared to wheat, it has a lower glycemic index and higher fiber content, which helps control blood sugar, and its relatively high dietary fiber can lower fasting blood sugar levels (Post *et al*., 2012). Taking teff lowers Cholesterol levels and blood pressure, improving blood sugar and insulin sensitivity in diabetics, and can help with gastroesophageal reflux disease, duodenal ulcer diverticulitis, constipation and several gastrointestinal disorders, including hemorrhoids (Wolter *et al*., 2013; Anderson *et al*., 2009) And if the person is overweight and obese, supplementing fiber has a great effect on weight loss, so it can be said that it is a grain that has the potential as an excellent food for people who are on a diet.

7. Conclusions

It should be understood that all populations and age groups in the world should be aware of

the risk of side effects and diseases that come from excessive consumption of flour. Therefore, in order to promote teff, it is necessary to develop various foods using teff and to pay attention to marketing to inform various media. It is expected that more research on teff will come out, and it is expected that gluten-free food will gradually develop.

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