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Literature Review: Potential of Sorghum Protein Isolate as an Alternative for Plant-Based Protein

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ABSTRACT

Protein intake is needed to have an optimal growth. In Indonesia, to fulfill the protein intake, society usually uses plant-based protein as an alternative because it has a more affordable price than animal-based protein. One of the plant-based proteins comes from sorghum. Sorghum has a low protein digestibility, so protein needs to be purified. Therefore, to develop more, it is necessary to isolate the protein. The literature review starts with problem identification, data collecting, sorting the obtained data, reading and analyzing, and compiling it into a systematic review. The results show that sorghum isolate protein has the potential to be an alternative to plant-based protein, as indicated by the functional properties. Food processing with sorghum protein isolate can improve product quality because it functions as an emulsifier in meat processing and bread dough..

Keywords: Functional Properties, Isolate Protein, Sorghum.

INTRODUCTION

Humans need protein intake for optimal growth (Fitri, 2012). Based on the source, there are two types of protein, animal and plant-based. In general, animal protein has better quality than plant-based protein because it contains more complete essential amino acids (Swarinastiti et al., 2018). Protein sources from animals have a higher price than plant-based. Therefore, many Indonesian people use plant-based protein as their alternative source. Compared to other plants, nuts and cereals contain enough protein to use as an alternative. One of the cereals that can be used as a high-end protein source is sorghum (Wulandari et al., 2021). Sorghum is the prestigious imported food and the third most wanted cereal after rice and corn (Suarni, 2012). Sorghum can be developed easily because it has good adaptability to dry land and has become one of the most eaten foods by the public (Dutta, 2017). Compared to rice, corn, and millet, sorghum has a more significant protein percentage, which 77-82% is filled by kafirin (Suarni, 2012; Xiong et al., 2019) However, one of the weaknesses of sorghum seeds as a food ingredient is their low protein digestibility. This is caused by several factors, including 0,10-3,60% tannins that can bind proteins and other content besides protein like carbohydrates, fats, and sugars (Dykes & Rooney, 2006; Suprijadi, 2012).

Purifying and simplifying the protein molecule will increase the protein digestibility because the protease enzyme will be easier to digest and hydrolyze protein (Astawan, 2013). Therefore, to develop it further, it is necessary to isolate the protein. Isolate protein is the result of protein isolation containing 90% dry basis protein, whereas concentrate contains 65% dry basis protein (Kumar et al., 2020). The isolation process can be carried out in various ways such as physical, enzymatic, and precipitation by isoelectric point.

METHODS

The literature review starts with problem identification, data collecting, sorting the obtained data, reading, analyzing, and compiling it into a systematic review. The method is mainly divided into two stages; The first stage is related to the data collecting, consisting of problem identification, determining library sources based on eligibility criteria with inclusion or exclusion criteria, data collecting, and sorting based on the suitability of the literature with the topics discussed. The second stage is processing the data that have passed the sorting process, consisting of Data analysis and interpretation and confirmation. Data confirmed will be included in the review, while unconfirmed data will be excluded.

RESULTS AND DISCUSSION

The nutritional components of sorghum are not much different than other cereals, such as corn, rice, and wheat in general. The nutritional component is determined by the variety of plants, which also affects the plant height, stem diameter, and the number of leaves of sorghum plants. Protein is the second-largest component in sorghum after carbohydrates. Using the proximate analysis, the protein content of sorghum seeds was analyzed at 10.4%, while the form of flour ranged from 6.34 to 8.29% (Suprijadi, 2012). Proximate is a quantitative chemical analysis method to determine the nutritional content of the material, such as water, ash, crude protein, crude fat, and carbohydrates (Faizah, Novita Ismi; Haryanti, 2020).

According to Ahza (1998) in (Suarni, 2004), sorghum flour has the potential to be a protein supplier, also relatively odorless, so it can be mixed with other cereal flours. Sorghum also contains tannins, which can interfere with the digestion of sorghum protein in the human body (Suprijadi, 2012). Nevertheless, it can be decreased by cooking or heating (Mesa-stonestreet et al., 2010). Therefore, to develop more, it is necessary to isolate sorghum protein (Wulandari et al., 2021).

Functional properties are the characteristics that are important for food processing. Protein has an effect on functional properties, including water absorption, oil absorption, emulsion capacity and stability, gel strength, and foam capacity and stability. Knowing the functional properties is important due to protein behavior during the process, storage, presentation, and it causes the food quality and accepted by consumers (Kinsella, 1979 in Ilaningtyas et al., 2006). Information about the functional properties can be known as follows :

Table 1. Protein Functionality in Selected Processed Foods

Functional Properties	Reaction Type	Type of Food
Solubility	Protein solvation, depending on pH	Beverage
Water absorption and water-binding	Hydrogen bonding, water absorption	Soups and gravies
Viscosity	Thickening, water binding	Meat, sausage, bakery, cake
Gelation	Protein matrix formation and precipitation	Meat, curd, cheese
Cohesion-adhesion	Protein adhesive properties	Meat, sausage, bakery, pasta
Elasticity	Gluten hydrophobic bonds, disulfide bonds in gel	Meat, bakery
Emulsification	Fat emulsion formation and stability	Sausage, soups, cake
Fat absorption	Fat-free binding	Meat, sausage, donut
Flavor binding	Absorption, adsorption	Bakery
Foaming	Stable film to trap gas	*Whipped toppings*, cake

Source : (Owusu-Apenten, 2004)

The functional properties of protein isolates can also be affected by the protein isolation process. The research of Mir et al. (2018) shows that extraction with higher pH will decrease the particle size of protein isolate. Particle size can affect the protein functional properties such as solubility, water absorption, and oil absorption. In addition, the extraction pH also causes an increase in water absorption, oil absorption, emulsion capacity, emulsion capacity, emulsion stability, foam capacity, and foam stability (Pratiwi et al., 2018). However, extreme pH extraction may cause protein denaturation, decreased protein content, and decreased functional properties. The higher protein content or purity in the isolate or concentrate, the higher the functional properties of protein isolate or concentrate.

Solubility

Table 2. Solubility from Previous Research Protein Plant-Based

References	Source of Protein	Solubility
(Sun et al., 2019)	Walnut Gluten	154,30%
(Jiang et al., 2021)	Akebia Seeds	-
(Liu et al., 2013)	Wheat	-
(Kongo-Dia-Moukala & Zhang, 2011)	Corn	-
(Khan et al., 2011)	Rice	-
(Espinosa-Ramírez & Serna-Saldívar, 2016)	Red Sorghum	0,51 g
(Wang et al., 2010)	Barley Bran	pH 3-8 minimum solubility pH 10 maximum solubility pH 10 : 60% pH 5 : 17%
	Endosperm	pH 3-8 minimum solubility pH 10 maximum solubility pH 1- : 55% pH 5 : 10%
(Patsanguan et al., 2014)	Rice Bran	-
(Hassan et al., 2010)	Wheat	pH 9: 52,52% pH 4: 5,66%
	Wheat Seeds	pH 10: 55,81% pH 4: 6,86%
(Mohamed et al., 2009)	Yellow Millet	pH 2 : 40% pH 4 and 5 : 20% pH 6 : 50-80%
	White Millet	
(Wulandari et al., 2019)	Red Bean Sorghum	-
	Red Bean Rice	-
	Red Bean Bran	-

Isolate protein is affected by protein solubility, pH content, and particle size. Solutions with alkaline pH have a higher solubility than acid pH because most amino acids will charge into harmful contents when the pH is higher than their isoelectric point. Smaller particle sizes, more hydrophilicity, and more soluble polypeptide components can produce protein isolate with high solubility (Thiansilakul et al., 2007). In addition, smaller protein molecules size leads to the exposition of more polar and ionized groups on the protein surface, which can increase the ability of protein molecules to form hydrogen bonds with water and lift up the solubility of protein isolate (Kempka et al., 2014). Using enzymatic methods can also increase the solubility of protein isolate because there is a centrifuge process to eliminate the insoluble protein fraction (Waglay et al., 2019).

Water Absorption

Table 3. Water Absorption from Previous Research Protein Plant-Based

References	Source of Protein	Water Absorption
(Sun et al., 2019)	Walnut Gluten	5,26 g/g
(Jiang et al., 2021)	Akebia Seeds	3,8 g/g
(Liu et al., 2013)	Wheat	2,54 g/g
(Kongo-Dia-Moukala & Zhang, 2011)	Corn	2,14 g/g
(Khan et al., 2011)	Rice	3,5 mL/g
(Espinosa-Ramírez & Serna-Saldívar, 2016)	Red Sorghum	2,65 g/g
(Wang et al., 2010)	Barley Bran	3,8 g/g
	Endosperm	4 g/g
(Patsanguan et al., 2014)	Rice Bran	2,69 g/g
(Hassan et al., 2010)	Wheat	-
	Wheat Seeds	-
(Mohamed et al., 2009)	Yellow Millet	6,06 g/g
	White Millet	7,15 g/g
(Wulandari et al., 2019)	Red Sorghum Seeds	1,33 g/g
	Red Sorghum Rice	1,62 g/g
	Red Sorghum Bran	1,58 g/g

Water absorption parameters are influenced by the amino acid composition of the protein, protein structure, particle size, surface hydrophobicity, and processing (Khan et al., 2011). The increase of protein polarity can affect the rise of water-bound. The hydrophilic and hydrophobic properties of the protein structure can bind water and oil simultaneously and change the structure, affecting the water absorption of protein concentrates (Khan et al., 2011). With a small particle size, it will be easier to elevate the level of protein adsorption to the water-oil interface. Thereby the emulsifying ability and water absorption also increase. This parameter is useful for improving the characteristics of bakery products. A past study proved that 5-10% protein isolate of sesame and sunflower seeds in the dough could increase the water absorption properties (El Adawy, 1997 in Alu'datt et al., 2012).

Oil Absorption

Table 4. Oil Absorption from Previous Research Protein Plant-Based

References	Source of Protein	Oil Absorption
(Sun et al., 2019)	Walnut Gluten	3,51 g/g
(Jiang et al., 2021)	Akebia Seeds	5,28 g/g
(Liu et al., 2013)	Wheat	2,98 g/g
(Kongo-Dia-Moukala & Zhang, 2011)	Corn	1,87 g/g
(Khan et al., 2011)	Rice	3 g/g
(Espinosa-Ramírez & Serna-Saldívar, 2016)	Red Sorghum	2,4 g/g
(Wang et al., 2010)	Barley Bran	2,74 g/g
	Endosperm	5,2 g/g
(Patsanguan et al., 2014)	Rice Bran	1,85 g/g
(Hassan et al., 2010)	Wheat	1,61 g/g
	Wheat Seeds	1,28 g/g
(Mohamed et al., 2009)	Yellow Millet	5,09 g/g
	White Millet	6,61 g/g
(Wulandari et al., 2019)	Red Sorghum Seeds	1,51 g/g
	Red Sorghum Rice	1,54 g/g
	Red Sorghum Bran	1,45 g/g

Similar to water absorption, oil absorption can be affected by protein content, protein structure, amino acids, and particle size. Protein structures that support fast absorption are lipophilic or amino acids with nonpolar properties (Sathe, 1982 in Hassan et al., 2010). Fat absorption is supported by several amino acids such as isoleucine, alanine, glycine, proline, and valine (Suarni & Firmansyah, 2016). The amino acid components can influence the value of this emulsion capacity in protein. The hydrophilic-lipophilic amino acid components of protein are able to bind oil and water, as well as the water mechanism to bind the hydrophilic chain and oil to the lipophilic chain (Dyahwarni, 2006). The emulsion capacity of protein isolate is closely related to food products that require this property to form fat emulsions, such as ground beef, sausage, and others. Research by (Budijanto & Sitanggang, 2011) proved that the emulsion capacity of winged bean seed protein isolate was 70.5% and stable for 4 hours. Thus, sorghum protein isolate has the potential to be a functional food ingredient for meat and other applications in food processing (Ilaningtyas et al., 2006).

Foaming Power and Foam Stability

Table 5. Foaming Power and Foam Stability from Previous Research Protein Plant-Based

References and Source of Protein	Foaming Capacity	Foaming Stability
(Sun et al., 2019)		
Walnut Gluten	102,64%	90,71%
(Jiang et al., 2021)		
Akebia Seeds	26%	86,59%
(Liu et al., 2013)		
Wheat	150%	91,67%
(Kongo-Dia-Moukala & Zhang, 2011)		
Jagung	50%	-
(Khan et al., 2011)	10,4 mL	71 minute
(Espinosa-Ramírez & Serna-Saldívar, 2016)		
Red Sorghum	-	-
(Wang et al., 2010)		
Barley Bran	pH 3 : 58% pH 5 : 30% pH 8 : 64%	pH 3 : 43% pH 5 : 68% pH 8 : 48%
Endosperm	pH 3 : 68% pH 5 : 14% pH 8 : 78%	pH 3 : 40% pH 5 : 72% pH 8 : 53%
(Patsanguan et al., 2014)		
Rice Bran	57,5%	-
(Hassan et al., 2010)		
Wheat	maximum at pH 8 : 1,60 ml foam/ml liquid	maximum at pH 10 : 0,103 ml of initial fluid
Wheat Seeds	maximum at pH 10: 1,69 ml foam/ ml liquid	maximum at pH 10: 0,106 ml of initial fluid
(Mohamed et al., 2009)		

Yellow Millet	124 g/ml	-
White Millet	137 g/ml	-
(Wulandari et al., 2019)		
Red Sorghum Seeds	47,50 ml/g/g	-
Red Sorghum Rice	56,25 ml/g	-
Red Sorghum Bran	38,75ml/g	-

The foaming power and foam stability of protein isolate can be affected by pH (Fennema, 1996). Solubility can influence protein adsorption at the air-water interface. High solubility increases the foam capacity (Hassan et al., 2010). Another cause of foam stability is the presence of other substances such as fat. The fat component can decrease the protein interaction by disrupting the hydrophobic surface and reducing the absorption of the water-air interface (Zayas, 1997)

Emulsion Capacity and Stability

Table 6. Emulsion Capacity and Stability from Previous Research Protein Plant-Based

References and Source of Protein	Emulsion Capacity	Emulsion Stability
(Sun et al., 2019)	42,06%	113,04%
(Jiang et al., 2021)	67,75%	74,01%
(Liu et al., 2013)	0,207	76,09%
(Kongo-Dia-Moukala & Zhang, 2011)	63,39ml/0,5 g	-
(Khan et al., 2011)	71%	46,9%
(Espinosa-Ramírez & Serna-Saldívar, 2016)	1,13 m2/g	-
(Wang et al., 2010)		
Barley Bran	- - -	pH 3 : 58% pH 5 : 30% pH 8 : 64%
Endosperm	- - -	pH 3 : 58% pH 5 : 33% pH 8 : 60%
(Patsanguan et al., 2014)		
Wheat Seeds	maximum at pH 10 : 1.69 ml foam/ml liquid	maximum at pH 10 : 0.106 ml of residual fluid / ml of initial fluid
(Hassan et al., 2010)		
Wheat	60,62%	57,95%

Wheat Seeds	70,82%	67,01%
(Mohamed et al., 2009)		
Yellow Millet	65%	-
White Millet	74%	-
(Wulandari et al., 2019)		
Red Sorghum Seeds	2,73%	-
Red Sorghum Rice	13,00%	-
Red Sorghum Bran	0,58%	-

Emulsion capacity is the ability to form an emulsion and maintain the stability of the emulsion. The emulsification of material is closely related to the balance of hydrophilic and lipophilic amino acid groups. Emulsion stability is one of the important functional properties to stabilize the emulsion system, such as cooking or heating. Several things that affect the emulsion power are protein concentration, mixing speed, type of protein, type of fat, and emulsion system (Rosida et al., 2014).

Based on table 3, the highest emulsion capacity was produced by akebia seeds protein at the number of 67.75%, while the highest emulsion stability was produced by walnut gluten protein isolate, which was 113.04%. The increase in emulsifying properties can be caused by the degradation of large protein molecules, an increase in hydrophobic groups, and an increase in protein solubility, which has an effect on increasing protein surface activity (Meinlschmidt et al., 2016).

Proteins easily diffuse to the oil-water surface. Proteins with higher concentrations have less possibility of diffusion because of the activation energy barrier for the protein to adsorb on the surface (Waglay et al., 2019). The ability of food proteins to form and stabilize emulsions is very important to controlling emulsion stability in the food industry (Liu et al., 2013). Excellent emulsifiers can reduce surface tension and resist coalescence to form small oil droplets in the emulsion, improve oil dispersion, and facilitate interactions at the oil-water surface. Therefore, the membrane surface will be easier to stabilize (Li et al., 2018).

CONCLUSION

Functional properties such as water absorption, oil absorption, emulsion capacity and stability, gel strength, and foam capacity and stability were positively correlated with protein content. The purer the protein, the better its functional properties due to factors such as particle size, other nutritional components, and the simpler protein structure. This makes sorghum protein isolate can be an option to be used in food ingredients such as bakery, cake, and meat products.

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