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EFFECT OF GERMINATION PERIOD ON SOME FUNCTIONAL AND ENGINEERING PROPERTIES OF SORGHUM FLOUR

ABSTRACT

Sorghum (red and white) were germinated for 24, 48, 72, and 96 h to determine the effect of germination on some functional and engineering properties of sorghum flour. The bulk density results for the red and white germinated sorghum are 0.620-0.673 g/cm^3 and 0.477-0.620 g/cm^3, respectively. Water absorption capacity values for the two samples are 116.630-125.970% and 81.643-98.293% while the oil absorption capacity ranged from 62.917 to 85.750% and 44.933 to 61.980%, respectively for the two samples. The dispersibility test for the two samples gave 85.67-87.33% and 83.00-84.67%. The swelling power at 55 °C are 2.54-2.67 and 2.70-3.26, at 75 °C, 3.62-4.68 and 3.85-4.56, and at 90 °C, 2.98-4.79 and 6.29-7.23, respectively for the two samples. For the engineering properties, the specific heat capacity ranged from 0.14 to 0.45 kJ/kg K and 0.12 to 0.14 kJ/kg K, thermal conductivity, from 0.55 to 1.67 W/mK and 1.01 to 1.24 W/mK and thermal diffusivity from 0.13 to 0.82 m^2/s and 0.11 to 0.12 m^2/s, respectively for red and white germinated sorghum flours. It can be concluded from this study that increased the values of bulk density, WAC, OAC, and dispersibility test of the two samples with the increase in germination period with the optimum germination period of 72 h. Engineering properties results indicated that germination had a beneficial effect on the thermal conductivity of the germinated red sorghum and the thermal conductivity and specific heat capacity of the white germinated sorghum with 96 h having the best result for both samples.

Keywords: germination, time, sorghum, flour, functional, engineering.

1. INTRODUCTION

Sorghum (*Sorghum bicolor)* is in the subfamily Panicoideae and the tribe Andropogoneae (the tribe of big bluestem and sugarcane) being a flowering plant in the grass family, is the fifth most important cereal after rice, wheat, maize, and barley. It is a major source of proteins and calories in the diet of a large sector of African population and is mostly consumed by the poorer part of the population in many countries (Belton and Taylor, 2004). It is an important crop worldwide used for food (as grain and in sorghum syrup or sorghum molasses), animal fodder, production of alcoholic beverages, and biofuels which is important in the arid regions, where the grain is one of the staple food for the poor and rural people (Dillon *et al*., 2007). Eight out of the 25 species are native to Australia, with some extending to Africa, Asia, Mesoamerica, and certain islands in the Indian and Pacific oceans (Dillon *et al*., 2004). One of the species is grown for grain, while the others are used as fodder plants and it is either cultivated in warm climates worldwide or naturalized in the pasture (BONAP, 2014). Although, sorghum as a food source has not been fully exploited due to its abundance in numerous phytochemicals (Cardoso *et al*., 2017), it represents an important ingredient in gluten-free formulations (Marengo *et al*., 2015). Traditionally, the technologies involved in the processing of sorghum include threshing, cleaning, washing, soaking, fermentation, and germination, wet and dry milling.

Germination is a phenomenon that occurs when a new plant is formed from a dry seed upon the inhibition of water, if the dry seed is not inactive and the conditions are favorable, it enters germination process. It is also a natural process that occurs during the growth of seeds when they meet the minimum condition for growth and development (Sangronis *et al*., 2006). It is also a processing method that improves the nutritional and functional properties of grains and legumes as well as digestibility according to Imtaiz and Burhan-Uddin (2012). The metabolic activity involved in germination, as a result of reactivation of dormant enzyme results in the production of secondary and primary metabolites which improves the nutritional and functional properties of the grain (Bohoua and Yelakan 2007; Abbas and Nushara, 2008).

Functional properties explain how ingredients behave during preparation and cooking and how they affect the finished food product in different ways such as how it looks, tastes, and feels. These are also the interaction between the physiochemical characteristics and chemical components of food (Sibian *et al*., 2017) associated with the nature of the environment which are measured (Kaur and Singh, 2005). These functional properties include dextrinisation, caramelization, water absorption capacity, bulk density, dispersibility, swelling power (capacity) and solubility index, water absorption index. Other functional properties include emulsification, hydration (water-binding), viscosity, foaming, solubility, gelation, cohesion, and adhesion.

The engineering properties of food are very important, if not essential, in the process design and manufacture of food products. These engineering properties can be classified as (translucency), electrical (conductivity and permittivity), mechanical (structural, geometrical, and strength) properties. These properties of food show the design of processes and/or machines for characterization, handling, and processing of the materials (Barbosa-Canovas *et al*., 2009). The basic information on engineering properties is of great importance and helps in achieving efficient process and equipment development.

Studies have been carried out on the effect of germination on sorghum quality (Elkhalia and Bernhardt, 2010; Phattanakulkaewmorie *et al*., 2011; Arouna, 2020). Meanwhile, there is a lack of information on the engineering properties of germinated sorghum flour. This study was therefore carried out to investigate the effect of the germination period on some of the functional and engineering properties of red and white sorghum flour.

2. MATERIALS AND METHODS

2.1 Materials

Sorghum grains (red and white)tray, bowl, cabinet dryer, water, malting tray, muslin cloth, hammer mill, sieve, measuring cylinder, centrifuge, spatula, aluminum foil, and weighing balance were purchased from a local market, Oshodi in Lagos. The study was conducted at Food Technology Laboratory, Federal Institute of Industrial Research Oshodi (FIIRO).

2.2 Sample Preparation

The method of Ocheme (2007) was adopted for the germination of sorghum. Two thousand grams (2000 g) of both red sorghum and white sorghum grains were sorted and washed using tap water. The washed sorghum was soaked in 2.5 *l* of tap water for 12 h. At the end of the soaking, the water was decanted and drained off and the grain was evenly spread on the muslin cloth in a malting tray. It was covered with the same material in a dark secluded area and germinated for 24, 48, 72, and 96 h. Water was sprinkled on the germinated grain at 24 h intervals to prevent it from drying out. At the end of the germination period, the grains were dried using a cabinet dryer at 60 °C for 4 h until a constant weight was observed. The de-rooting and de-shooting were done manually by rubbing the grains between the palms and the grains were winnowed to separate the dried grind from its roots and shoots. It was milled using a hammer mill and packaged using a zip lock pack.

2.3 Functional Properties

Bulk density: Bulk density was carried out as described by the gravimetric method described by Okaka *et al*. (1991), with some modifications. The sample (3 g) was weighed and placed in a 25 cm^3 measuring cylinder on a benchtop and was tapped 10 times on a rubber-laden table top to eliminate air space between the flour in the cylinder. The final volume of the sample was measured and expressed in g/cm^3.

$$Bulk\ density(g) = \frac{weight\ of\ the\ flour(g)}{\text{volume occupied by the flour before tapping}}$$

Water and oil absorption capacities: Water absorption capacity was carried out as described by Lawal and Adebowale (2005), with some modifications. Two grams (2 g) of the sample was added to 10 cm^3 of distilled water in a weighed 25 cm^3 centrifuge tube. The sample was vortex for 1 min and allowed to stand for 30 min at 25 °C before being centrifuged at 4000 rpm for 25 min. The supernatant was decanted and the sediment together was weighed. For the oil absorption, 10 cm^3 of refined vegetable oil was used in place of distilled water.

Dispersibility: The dispersibility of the flour was measured according to Kulkami *et al*. (1991) method with some modifications. Five grams (5 g) of each sample was suspended in a 100 cm^3 measuring cylinder and distilled water was added to reach the 50 cm^3 mark. The setup was stirred vigorously with a glass rod and was allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 100.

$$dispersibility = 100 - volume\ of\ settled\ particles$$

Swelling capacity: The swelling capacity of the flour was determined as described by Li and Yeh (2001) and Adeboye and Singh (2008) with little modification. The swelling capacity depends on size of particles, types of variety, and types of processing method or unit operation. It is the quality criterion in some good formulations as bakery products. The sample, one gram (1 g) was weighed into the centrifuge tubes and 10 cm^3 of distilled water was added. The tube was heated at 55, 75, and 90 °C for 30 min with occasional stirring using a water bath shaker. The supernatant was decanted carefully and sediment was weighed.

2.4 Engineering Properties

Specific Heat Capacity: This method was carried out according to Choi and Okos (1986), using a Tempos Thermal Analyzer. A certain amount of the sample was poured into the container to the brim and a node was inserted into it. The machine read the specific heat capacity and it was recorded. It was allowed to cool for 15 min before the next experiment was carried out.

Thermal Conductivity: The method of Choi and Okos (2003) was used to determine the thermal conductivity of flour and thermal conductivity, k, was expressed in W/mK. It was carried out by the use of a Tempos Thermal Analyzer. A certain amount of the sample was poured into the container to the brim and a node was inserted into it. The machine reads the specific heat capacity and it was recorded. It was allowed to cool for 15 min before the next experiment was carried out.

Thermal Diffusivity: This is done by using the formula of Lide and David (2009). Thermal diffusivity (α) is the thermal conductivity (k) divided by bulk density (ρ) and specific heat capacity (Cp) at constant pressure and the SI is m^2/s. The thermal diffusivity will be calculated using:

$$\alpha = k/\rho Cp$$

It was carried out by the use of a Tempos Thermal Analyzer. A certain amount of the sample was poured into the container to the brim and a node was inserted into it. The machine reads the specific heat capacity and it was recorded. It was allowed to cool for 15 min before the next experiment was carried out.

Statistical Analysis

All experiments were done in three replicates and values were presented in tables as the means of three determinations. The statistical significant differences were evaluated by one-way analysis of variance (ANOVA) at the 5% significance level.

3. RESULTS AND DISCUSSION

3.1 Functional Properties

The functional properties of germinated red and white sorghum flour are as shown in Tables 1 and 2, respectively. The bulk density of red germinated sorghum flour ranged from 0.62 to 0.67 g/cm^3 with the sample germinated at 24 h having the lowest bulk density while the sample germinated at 72 h had the highest value while the bulk density for germinated white sorghum flour ranged from 0.48 to 0.62 g/cm^3. There was an increase in the bulk density of the two flour samples from 24 h to 72 h and it started reducing when it got to 96 h for the two samples. This reduction may be due to the change that occurred during germination which led to the breakdown of a complex compound such as starch, fat, and protein. The bulk density of a food material affects its mouthfeel as well as the type of packaging material used (Awoyale *et al*., 2020; Awuchi *et al*., 2019) that is increasing bulk density requires lesser package requirement.

Bulk density can be affected by different factors such as preparation, treatment, and storage of grains. Lower bulk density might be a result of softening of grain during soaking which produced smaller flour particles after milling (Siddiqua *et al*., 2019). The bulk density of a material is affected by the particle size and density of the food. There was a significant difference ($p<0.05$) in the bulk density of the red germinated sorghum samples and there was no significant difference between the 48 and 96 h sample of the germinated white sorghum flour, but there was a significant difference between samples 24 and 72 h.

The water absorption capacity of red germinated sorghum flour ranged from 116.63 to 125.97% with sample germinated at 72 h having the lowest water absorption capacity while sample germinated at 96 h had the highest value. There was stability between 24 and 48 h, a reduction at 72 h, and an increase at 96 h. The WAC for the white germinated sorghum flour ranged from 81.64-98.29%. There was an increase between 24 and 48 h and stability occurred between 72 and 96 h. The increase might be because there was a production of compounds with good water absorption capacity such as soluble sugars (Ocheme *et al.*, 2015). The increase may also be due to a change in the quality of protein upon germination and also the breakdown of polysaccharide molecules which increases the site for the interaction with water and holding water (Elkhalifa and Bernhardt, 2010).

There was no significant difference in the water absorption capacity of the samples 24 and 48 h germinated red sorghum flour, 72 and 98 h were significantly different for germinated red sorghum flour. A significant difference in the water absorption capacity of the samples 24 and 48 h germinated white sorghum flour was observed, so also, 72 and 96 h germinated white sorghum flours were significantly different. The increase in water absorption capacity observed is in agreement with the report of Gernah *et al*. (2011) who reported an increase in the water bounding capacities of maize as a result of malting. There was a similar result gotten by Ocheme and Chidinma (2008) for the germination of millet flour. Water absorption capacity is the ability of a product to associate with water under a condition where water is limiting. Proteins are mainly responsible for high water intake and to a lesser extent, starch and cellulose at room temperature (Afoakwa, 1996). Water absorption capacity is important in foods where water is imbibed without the dissolution of protein, thus increasing their viscosity and body thickening (Seena and Sridhar, 2005). Higher value water absorption capacity helps to improve softness, bulkiness, consistency of the product, and reduce the viscosity (Oyarekua and Adeyeye, 2009). Flours with good water absorption capacities are useful for baking (Ocheme *et al.*, 2015).

The oil absorption capacity for red germinated sorghum flour range from 62.92 to 82.04% with 24 h sample having the lowest oil absorption capacity while 96 h have the highest value while the OAC for white germinated sorghum flour ranged from 44.93 to 61.98%. Oil absorption capacity is the ability of food or food ingredients to absorb oil or fat. The ability of protein to bind fat is important, since fats act as flavor retainer and increase the mouth feel of foods, improve palatability, extend shelf life of bakery products, meat extenders, doughnuts, pancakes, baked goods, and soup mixes (Oluwalana *et al*., 2011).

Germination of grain improves the oil absorption capacity as a result of the entrapment of oil-related to the non-polar side chains of proteins (Giani and Bekebain, 1992). It was observed in this study that the OAC of germinated red sorghum flour was not constant while there was an increase in the OAC of white germinated sorghum flour increased from 24 h to 72 h, this increase is in line with the earlier work of Ocheme *et al.* (2015) and also in line with the earlier work of Imtaiz *et al*. (2011). Food with good oil absorption capacity can be used as meat replacers and extenders. There were significant differences ($p<0.05$) in the oil absorption capacity for the two samples of flour.

There was a significant difference ($p<0.05$) in the results of swelling capacity. The ranges of results are 2.64-2.67 at 55 °C with 24 h having the lowest swelling power and 96 h having the highest swelling power, 4.26-4.68 at 75 °C with 24 h having the highest swelling power and 96 h having the lowest swelling power and 3.57-4.79 at 90 °C with 24 h having the highest swelling power and 48 h having the lowest swelling power for the germinated red sorghum samples. While for the germinated white sorghum samples, the results ranged from 3.07 to 3.26 at 55 °C with 96 h having the highest swelling power and 48 h having the lowest swelling power, 4.18 to 4.56 at 75 °C with 96 h having the highest swelling power and 48 h having the lowest swelling power and 6.29 to 7.23 at 90 °C with 24 h having the highest swelling power and 96 h having the lowest swelling power. There was an increase in the swelling power of the red germinated sorghum flour at 55 and 75 °C and a decrease at 90 °C and there was a variance in the swelling power at 55 and 75 °C and a total reduction at 90 °C. Swelling power depends on the nature of the material and the type of treatment used. Biopolymers of starch contribute to the development of these characteristics. Swelling power can also be related to water absorption index of starch-based flour during heating.

The dispersibility of germinated red sorghum ranged from 86.00 to 87.33% with 96 h having the highest value and 48 h and 72 h having the lowest value; that of germinated white sorghum flour ranged from 83.00 to 84.33% with 48 and 72 h having the highest value and 96 h having the lowest value. The ability of flours to go into dispersion without formation of lumps is a very important property especially in instant cold or hot mixes (Ikegwu and Okoli, 2011). The higher the dispersibility the easier it is to reconstitute giving fine consistency dough during mixing (Adebowale *et al*., 2008). The results gotten are in line with the previous work of Adebowale *et al*. (2012) on the functional properties and biscuit-making potentials of sorghum- wheat flour composite. For the red germinated sorghum flour, there was no significant difference between 48 h and 72 h germinated red sorghum and there was a significant difference between the 24 h and 96 h germinated red sorghum. For the white germinated sorghum flour there was no significant difference between the 48 h and the 72 h sample but there was a significant difference between the 24 h and 96 h germinated samples.

Table 1: Functional Properties of Germinated Red Sorghum

Germination Period (h)	Bulk Density (g/cm^{3})	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Dispersibility (%)	Swelling Power		
					Temperature 55 °C	75 °C	90 °C
24	0.62^{a}	119.96^{b}	62.92^{a}	86.00^{b}	2.64^{b}	4.68^{c}	4.79^{b}
48	0.63^{b}	119.97^{b}	85.75^{d}	85.67^{a}	2.54^{a}	3.62^{a}	3.10^{a}
72	0.67^{d}	116.63^{a}	76.53^{b}	85.67^{a}	2.54^{a}	3.74^{ab}	2.98^{a}
96	0.64^{c}	125.97^{c}	82.04^{c}	87.33^{c}	2.67^{c}	4.26^{bc}	3.57^{a}

Values represent means of triplicate reading, follow by different lowercase letter
Means within the same row with different alphabets are significantly different ($p \leq 0.05$)

Table 2: Functional Properties of Germinated White Sorghum Flour

Germination Period (h)	Bulk density (g/cm^{3})	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Dispersibility (%)	Swelling Power		
					Temperature 55 °C	75 °C	90°C
24	0.48^{a}	81.64^{a}	44.93^{a}	84.33^{c}	3.07^{b}	4.18^{ab}	7.23^{c}
48	0.53^{ab}	98.29^{c}	54.23^{b}	84.67^{b}	2.70^{a}	3.85^{a}	6.89^{bc}
72	0.62^{b}	89.99^{b}	61.98^{d}	84.67^{b}	3.15^{c}	4.23^{ab}	6.67^{b}
96	0.58^{ab}	89.99^{b}	57.10^{c}	83.00^{b}	3.26^{d}	4.56^{b}	6.29^{a}

Values represent means of triplicate reading, follow by different lowercase letter
Means within the same row with different alphabets are significantly different ($p \leq 0.05$)

3.2 Engineering Properties

The engineering properties of the flour range are shown in Tables 3 and 4, respectively. The specific heat capacity of the red germinated sorghum flour ranged from 0.14 to 0.24 (kJ/kgK) with 24 h having the lowest value and 96 h having the highest value and ranging from 0.13 to

0.14 (kJ/kgK) for the white germinated sorghum flour with 48 h having the lowest value and 96 h having the highest value. There were significant differences ($p<0.05$) between the samples of red germinated sorghum flour and there were no significant variations for 24 and 72 h germinated white sorghum flour but 48 and 96 h were significant ($p<0.05$) different**.** Specific heat capacity is the measure of the amount of heat energy required to change the temperature of 1 kg of a material by 1 K. It indicates how much energy is needed to cool and heat an object or food substance by a given amount. It also gives us information as to how long the heating or cooling process will take under a given specific supply as well as the cost implication. Specific heat capacity also finds application in heat conduction, convection, and radiation, length and volume expansions, phase changes, etc. The sample with the highest specific heat capacity is cost-effective and shows that it will not consume much energy and it will not take a longer time to heat up or cool down.

The thermal conductivity of the red germinated sorghum flour ranged from 1.07 to1.67 W/mK with 48 h having the lowest value and 96 h having the highest value. The thermal conductivity of the white germinated sorghum flour ranged 1.09 to 1.24 W/mK with 48 h having the lowest value and 96 h having the highest value. There were significant differences ($p<0.05$) among the samples. Thermal conductivity refers to characteristics or ability of a material to transfer and conduct heat. It can be used to predict heat flux in some operations like cooking, baking, drying, etc (Ramesh, 2000). The results of thermal conductivity obtained in this study proved that the flour has a good baking property. Knowledge of the product properties, including thermal conductivity as a function of processing conditions, is needed to predict the water and temperature distribution in the product during baking. In the baking process, baking products undergo physical, chemical, and biochemical changes that result in expansion of bulk volume, evaporation of water, formation of porous structure, denaturation of protein, gelatinization of starch, formation of crust, and browning reactions. During such processes, ovens are powered by gas, electricity, firewood, charcoal, or microwaves to generate the required heat. It occurs through molecular agitation and contact and does not result in the bulk movement of the solid itself. Heat moves along a temperature gradient, from an area with a high temperature and high molecular energy to an area with a lower temperature and lower molecular energy.

The thermal diffusivity of the red germinated sorghum flour ranged from 0.13 to 0.14 m^2/s with 96 h having the lowest value and 48 h having the highest value. The thermal diffusivity of the white germinated sorghum flour ranged from 0.11 to 0.13 m^2/s with 72 h having the lowest value and 24 h having the highest value. There were significant differences ($p<0.05$) in the samples. Thermal diffusivity is a measure of the rate of heat transfer of material from the hot side to the cold side. It is a physical property because it is a combination of physical properties such as conductivity, density, and specific heat capacity and it plays an important role in influencing the movement and behavior of heat. A material with high density is composed of atoms or molecules tightly packed together. So a material of high density will determine how fast heat can be transferred by limiting the speed and distance that heat can travel through the object. Thermal diffusivity determines how rapidly heat will flow within the material or the rates of temperature spread. It measures the rate at which heat disperses throughout an object or body. A material that conducts heat efficiently must be able to have effective heat diffusion properties to facilitate heat transfer.

Table 3: Engineering Properties of Germinated Red Sorghum Flour

Germination Time (h)	Specific Heat Capacity	Thermal Conductivity	Thermal Diffusivity

	(kJ/kgK)	(W/mK)	(m^2/s)
24	0.14^b	1.07^b	0.13^a
48	0.45^a	0.55^a	0.82^d
72	0.19^c	1.14^c	0.17^c
96	0.24^d	1.67^d	0.14^b

Values represent means of triplicate reading, follow by different lowercase letter
Means within the same row with different alphabets are significantly different ($p \leq 0.05$)

Table 4: Engineering Properties of Germinated White Sorghum Flour

Germination Time (h)	Specific Heat Capacity (kJ/kgK)	Thermal Conductivity (W/mK)	Thermal Diffusivity (m^2/s)
24	0.13^b	1.09^b	0.12^b
48	0.12^a	1.01^a	0.12^b
72	0.13^b	1.17^c	0.11^a
96	0.14^c	1.24^d	0.11^a

Values represent means of triplicate reading, follow by different lowercase letter
Means within the same row with different alphabets are significantly different ($p \leq 0.05$)

4. Conclusion

Functional properties are important in determining food material behavior among other functions. It can be concluded from this study that germination had beneficial properties on bulk density, WAC, dispersibility test, and OAC of the two samples with flour germinated at 72, 48, and 96 h having the best results. Engineering properties are also important in food processing in determining the most effective and efficient process design, machines, controls, and structure among other functions. It can be concluded from this study that germination had a beneficial effect on the thermal conductivity of the germinated red sorghum and the thermal conductivity and specific heat capacity of the white germinated sorghum with 96 h having the best result for both samples.

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Correlation Data
Correlation between INDEPENDENTS variables

Table 1a: Functional Properties of Germinated Red Sorghum

	Germination Period (h)	Bulk Density (g/cm^3)	Water Absorption Capacity (%)	Oil Absorption Capacity	Dispersibility (%)	Swelling Power		
						55 °C	75 °C	90 °C
Germination Period (h)	1	0.597614305	0.48750437	0.621187664	0.65165551	0.172093253	-0.300520743	-0.590192888
Bulk Density (g/cm^3)		1	-0.396650218	0.27761327	-0.128836848	-0.457090621	-0.554540476	-0.697950711
Water Absorption Capacity (%)			1	0.277954058	0.93640005	0.795272134	0.388925548	0.191965709
Oil Absorption Capacity				1	0.17273266	-0.349925468	-0.776237049	-0.845481416
Dispersibility (%)					1	0.839295672	0.436353568	0.164732719

Table 2a: Functional Properties of Germinated White Sorghum

	Germination Period (h)	Bulk density (g/cm^3)	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Dispersibility (%)	Swelling Power		
						55 °C	75 °C	90 °C
Germination Period (h)	1	0.828662607	0.318126315	0.796595317	-0.648206615	0.542277091	0.675322151	-0.995358008
Bulk Density (g/cm^3)		1	0.337872678	0.976162768	-0.14687682	0.428127801	0.401207896	-0.779178371
Water Absorption Capacity (%)			1	0.531010135	0.173644144	-0.620429469	-0.462036168	-0.353836622
Oil Absorption Capacity				1	-0.056583884	0.229320553	0.231111546	-0.757902889
Dispersibility (%)					1	-0.634904012	-0.843550358	0.686389527

Table 3a: Engineering Properties of Germinated Red Sorghum Flour

	Germination Time (h)	Specific Heat Capacity (kJ/kgK)	Thermal Conductivity (W/mK)	Thermal Diffusivity (m^2/s)
Germination Time (h)	1	0.037898096	0.67347996	-0.237445089
Specific Heat Capacity (kJ/kgK)		1	-0.613794726	0.956476517
Thermal Conductivity (W/mK)			1	-0.815328732
Thermal Diffusivity				1

Table 4a: Engineering Properties of Germinated White Sorghum Flour

	Germination Time (h)	Specific Heat Capacity (kJ/kgK)	Thermal Conductivity (W/mK)	Thermal Diffusivity (m^2/s)
Germination Time (h)	1	0.632455532	0.791807249	-0.894427191
Specific Heat Capacity (kJ/kgK)		1	0.944098862	-0.707106781
Thermal Conductivity (W/mK)			1	-0.899779997
Thermal Diffusivity				1