Changes of nutritional components of pre-evaporated sorghum’s panicle during storage

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Abstract. Sorghum is a potential food ingredient with adequate nutritional content like other cereals, and has added value with high mineral Fe content. However, sorghum has the disadvantage of high tannin content which is antinutrient and susceptible to warehouse pests. Storage of sorghum in panicle form by providing hot steam treatment will provide added value because it can extend shelf life. The purpose of this study was to determine the effect of evaporation treatment on sorghum quality during storage. This study used a completely randomized design with 3 replications. The tried factors included sorghum (S) varieties, namely: Numbu (S1), Local (S1); evaporation time (T), i.e. 0 minutes / without evaporation (T0), 15 minutes (T1), 25 minutes (T2), 35 minutes (T3); and shelf life (L); 0 months (L0), 2 months (L1), 4 months (L2). The results showed that the evaporation treatment was effective in maintaining the nutritional content of sorghum both Local and Numbu varieties, reducing yield loss due to warehouse pest attacks and reducing its tannin content. Treatment of sorghum panicle evaporation for 15 minutes, both Local and Numbu varieties of sorghum can maintain nutritional content for up to 4 months with an average water content of 11.37%, ash content of 1.89%, fat content of 2.65%, protein content 8.92%, carbohydrate 75.15%, yield loss of 9.94%, and normal aroma. Sorghum storage technology with the evaporation method can reduce tannin components so that it is an added value because it is expected that sorghum flour ingredients contain very low tannin and its contribution for food diversification.

1. Introduction

In Indonesia, various research have been conducted on the use of sorghum as a food ingredient in the form of polished product which can be processed into traditional, semi-traditional and modern foods. This shows that sorghum can substitute for glutinous rice which is relatively expensive [1]. Previous studies show that the form of sorghum flour can be processed into various food products, such as noodles, bread, various cakes, and various cookies [2-3]. By improving the quality of sorghum flour by modifying it, it is hoped that it will improve the rheological properties of flour to produce higher quality processed products [4]. Sorghum flour can also be made into analog rice using extrusion technology [5].

Sorghum as a potential food ingredient with nutritional composition is considered adequate and has functional components, to support functional food diversification. The content of tannins in sorghum makes it a specific food, which in small amounts is useful as an anti-oxidant but in high concentrations has an anti-nutritional effect [3]. Food sorghum is gluten-free, has antioxidant properties, and has a low glycemic index,
making it safe for consumption by diabetics [6], source of phenolic compounds depending on genotype [7]. Sorghum also has low digestibility, cholesterol lowering effect, antioxidant, anti-inflammatory, and carcinogenic properties [8]. The disadvantage of sorghum as a food ingredient is that it has a relatively low shelf life is easily attacked by warehouse pests, but in the form of flour has a relatively longer shelf life [1]. Therefore, if post-harvest handling is inadequate, the quality and quantity of sorghum obtained are very low.

The problem with sorghum is that soon after harvest, panicle must be processed immediately because it is easily attacked by warehouse pests, especially during the rainy season, while farmers at harvest time do not have time because they must immediately cultivate the land for planting other commodities. The purpose of this study was to determine the physical and physicochemical changes of sorghum during storage by using the hot stem method before storage. This technology can be applied by farmers so that it can extend the shelf life of sorghum in panicle form before further processing.

2. Materials and Methods
The research was conducted at the Cereal Crops Research Institute in 2018. The material used in this study was sorghum panicle which consisted of two varieties (Numbu and Local). The equipment used is a water bath, several equipment and additional materials as needed are carried out at the Processing Laboratory of the Cereal Crops Research Institute and instruments for tannin analysis.

2.1. Research Stages
Harvesting is done during the rainy season, this is done to anticipate post-harvest problems of sorghum if it is physiologically ripe (harvesting age) when there is rain. Sorghum samples in the form of panicles of the Numbu and Local varieties from the harvest were put in a water bath (hot water steam) container with a temperature of 65-70°C. Each treatment in the form of 10 panicles was evaporated for 0 minutes (without evaporation), 15 minutes, 25 minutes, and 35 minutes. The steam treatment will penetrate the sorghum seeds so that they can kill microorganisms, but the quality of the seeds is still quite maintained and suitable as food. Then the samples that have been given evaporation treatment are stored for 0, 2, 4 months. During the storage process, samples were observed proximately (samples were crushed using a blender), tannins, and warehouse pest attacks (by separating damaged/perforated seeds and calculating the percentage of damage).

2.2. Experimental design
The study was conducted using a completely randomized design, each treatment was repeated three times. The treatment that was tried consisted of three factors including varieties of sorghum (S), namely: Numbu (S1), Local (S1); evaporation time (T), namely: 0 minutes/without evaporation (T0), 15 minutes (T1), 25 minutes (T2), 35 minutes (T3); and shelf life (L); 0 months (L0), 2 months (L1), 4 months (L2). The duration of evaporation refers to the previous preliminary research.

Parameters observed in this study were chemical and physical variables which included moisture content (oven method 105°C), ash content (furnace method 550°C), fat content (extraction method with petroleum ether solvent/Kyltex apparatus), protein content (micro Kyeldahl method), carbohydrates (by difference), tannin content (Folin Ciocalteu method), and warehouse pest attack.

The observed data were then analyzed using the F 5% test and if it showed a significant difference, it was continued with the Least Significant Difference (LSD) test.

3. Result and Discussion
Sorghum varieties Numbu and local varieties (Figure 1) have a different color appearance. The sorghum of the Numbu variety has a creamy white color while the sorghum of the Local variety has a reddish-brown color. The difference in color appearance will affect the shelf life. After harvesting, the two types of sorghum (Figure 1) with 10 panicles per treatment each were put in a water bath (hot water steam) with a temperature
of 65-70°C (Figure 2). Hot water vapor penetrates the sorghum seeds and it is hoped that the microorganisms inside will be vanished, but the quality of the seeds is still quite maintained and suitable as food. According to [9-10], evaporation aims to vanish microorganisms to minimize the level of damage to both nutrition and physical.

Sorghum that has been given evaporation treatment were stored for 0 minutes, 15 minutes, 25 minutes, and 35 minutes was then stored for 0, 2 months, and 4 months (Figure 3). Storage aims to determine the extent of damage from the sorghum. The longer the storage time, the more sorghum will be damaged physically and its components of food. Observations showed that the evaporation treatment before storage could increase the shelf life of sorghum panicles to minimize the level of damage, both chemical and physical.
3.1. Chemical Properties

Based on the results of the analysis of the effect of evaporation time, there was a significant difference in the 5% LSD test on the proximate composition which included water, ash, fat, protein, and carbohydrate content during the storage period. The results of the analysis of the proximate composition are presented in the following table. Changes in the water content of sorghum seeds of Numbu and Local varieties are presented in Table 1.

Table 1. Moisture content (%) of Numbu and Local varieties of sorghum during storage. Maros 2018.

| Evaporation time (minutes) | Numbu varieties (month of storage) | Local Varieties (month of storage) |
|---------------------------|----------------------------------|-----------------------------------|
|                           | 0                                | 2                                 | 4 | 0 | 2 | 4 |
| 0                         | 12.54 a                          | 13.27 a                           | 14.19 a | 12.50 a | 13.27 a | 14.55 a |
| 15                        | 10.26 b                          | 10.67 b                           | 11.29 b | 10.26 b | 10.67 b | 11.45 b |
| 25                        | 9.77 bc                          | 10.57 b                           | 11.10 b | 9.79 c  | 10.59 b | 11.37 b |
| 35                        | 9.79 c                           | 9.93 c                            | 10.42 c | 8.77 d  | 9.93 c  | 11.21 b |

Note: Numbers in the column followed by the same letter mean that they are not significantly different at the 5% LSD test level.

It can be seen that the storage of sorghum seeds in panicle form with the application of steam, can maintain the water content, although there is a change but not significantly different. In contrast to storage without steam application for both varieties, the two varieties showed that they had started storage for two months, had increased water content, and began to be attacked by warehouse pests causing damage to seeds resulting in a decrease in nutritional components.

The longer the evaporation in panicles, both Numbu and Local varieties, the lower the moisture content. The highest water content in sorghum without evaporation is 12.54% in the Numbu variety and 13.27% in the local variety. While the highest water content in evaporation for 35 minutes is 8.77%. Evaporation causes a softening of the texture so that after the panicles are air-dried there will be a release of water in the food so that the water content becomes low. Low water content in sorghum panicles will increase its shelf life because water is a good place for microbial growth. This is in line with the opinion of [11], the lower the water content of a food ingredient, the more inhibited microbial growth will be because free water is needed for the growth and activity of these microbes. The water content will increase with the length of storage, at month 0 storage the average water content is 10.46%, 2 months storage is 11.11%, then increases in the fourth month with an average of 11.94%. During storage, the moisture content of food will adjusted to the RH of the environment, resulting in an increase in water content. The water content of sorghum seeds during storage is shown in Table 2.

Table 2. Ash content (%) of Numbu & Local varieties of sorghum during storage. Maros 2018.

| Evaporation time (minutes) | Numbu varieties (month of storage) | Local Varieties (month of storage) |
|---------------------------|----------------------------------|-----------------------------------|
|                           | 0                                | 2                                 | 4 | 0 | 2 | 4 |
| 0                         | 1.99a                            | 1.78a                             | 1.67a | 2.05a | 1.80b | 1.72b |
| 15                        | 1.94a                            | 1.89a                             | 1.86a | 1.99ab | 1.97a | 1.93a |
| 25                        | 1.92a                            | 1.85a                             | 1.81a | 1.96b  | 1.95a | 1.90a |
| 35                        | 1.91a                            | 1.80a                             | 1.80a | 1.93b  | 1.92a | 1.88a |

Note: Numbers in the column followed by the same letter mean that they are not significantly different at the 5% LSD test level.
The content of ash content in panicles of sorghum indicates the presence of mineral content in it. The evaporation treatment did not show any significant difference to the ash content of both the Numbu and Local varieties. It can be seen that the longer the storage, the lower the ash content. This is in accordance with the research results of [11], that during storage, the mineral content in food will decrease along with the increasing water content.

The results of the analysis of fat content in (Table 3), show that the longer the evaporation the fat content of sorghum decreased, both for the Numbu variety and the Local variety (Table 3).

Table 3. Fat content (%) of Numbu and Local varieties of sorghum during storage. Maros. 2018.

| Evaporation time (minutes) | Numbu varieties (month of storage) | Local Varieties (month of storage) |
|---------------------------|------------------------------------|------------------------------------|
|                           | 0                                  | 2                                  | 4                                  | 0                                  | 2                                  | 4                                  |
| 0                         | 3.39a                              | 2.71a                              | 2.80a                              | 3.25a                              | 2.9a                               | 2.70a                              |
| 15                        | 2.99ab                             | 2.78a                              | 2.69b                              | 2.89b                              | 2.7bc6                             | 2.64a                              |
| 25                        | 2.85b                              | 2.75a                              | 2.60b                              | 2.78bc                             | 2.65bc                             | 2.61a                              |
| 35                        | 2.81c                              | 2.72a                              | 2.55b                              | 2.65c                              | 2.60c                              | 2.58a                              |

Note: The number in a column followed by the same letter means that it is not significantly different at the 5% LSD test level.

Control fat content (without evaporation) in Numbu variety sorghum was 3.39% and Local variety was 3.25%. Then it decreases until it evaporates for 35 minutes with this very decrease in fat content. The fat content in sorghum decreased with the longer shelf life. The average month 0 is 2.95%, month 2 is 2.72% until month 4 is 2.65%. So that during 2 months of storage there was a decrease in fat content in sorghum by 7.80% and for 4 months by 10.17%. The decrease in fat content during storage is due to the fact that during storage, fat which is a macromolecular component will be degraded into micro molecular components. According to [12], during storage, there will be a process of hydrolysis of fat content in foodstuffs into free fatty acids and glycerol. The reduction of fat in flour foods is an advantage, because high levels of fat together with amylose can inhibit the development of starch granules by forming complexes that inhibit the increase in peak viscosity at high pasting temperatures [13, 14].

Likewise, with protein content, evaporation treatment on sorghum panicles (Table 4) caused a decrease in protein content. The highest protein content in panicles without evaporation was 10.09% in Numbu sorghum, and Local sorghum at 9.18%. The heating treatment causes the infiltration of hot water vapor into the sorghum so that the protein will be denatured. According to [15], denatured proteins will undergo structural changes to become secondary, tertiary, and quaternary. The level of protein damage increases with the higher the temperature and the longer processing time [16].

The longer the storage, the lower the protein content (Table 4) and carbohydrates (Table 5), this is due to the reshuffling of macromolecular compounds into micromolecular compounds. The average protein and carbohydrate content in the 0th month was 9.23% and 75.72%, respectively, then decreased in the 2nd month by 8.77% and 75.53% until the 4th month by 8.33% and 75.25%.
Table 4. Protein content (%) of Numbu and Local varieties of sorghum during storage. Maros 2018.

| Evaporation time (minutes) | Numbu varieties (month of storage) | Local Varieties (month of storage) |
|---------------------------|------------------------------------|-------------------------------------|
|                           | 0   | 2   | 4   | 0   | 2   | 4   |
| 0                         | 10.09a | 8.47b | 7.05b | 9.18a | 7.75b | 6.05 |
| 15                        | 9.28b | 9.12a | 9.03a | 9.10ab | 8.87a | 8.81 |
| 25                        | 9.15b | 9.02a | 8.91a | 8.99b | 8.90a | 8.87 |
| 35                        | 9.12b | 9.09a | 8.99a | 9.02b | 8.95a | 8.90 |

Note: The number in a column followed by the same letter means that it is not significantly different at the 5% LSD test level.

During the storage of sorghum, there will be changes in complex compounds into simpler compounds where carbohydrates will become simple sugars and proteins will become amino acids. According to Nurdjannah et al. (2014) [17] during storage, food will carry out a metabolic process by breaking down macromolecular compounds into micromolecules.

Table 5. Carbohydrate content (%) of Numbu and Local varieties of sorghum during storage. Maros 2018.

| Evaporation time (minutes) | Numbu varieties (month of storage) | Local Varieties (month of storage) |
|---------------------------|------------------------------------|-------------------------------------|
|                           | 0   | 2   | 4   | 0   | 2   | 4   |
| 0                         | 73.39b | 73.77c | 74.29c | 74.22c | 74.28c | 74.98a |
| 15                        | 75.62a | 75.54b | 75.13c | 75.76bc | 75.73b | 75.17a |
| 25                        | 76.31a | 75.74b | 75.50c | 76.47b | 75.88ab | 75.25a |
| 35                        | 76.37a | 76.53a | 76.32a | 77.64a | 76.60a | 75.43a |

Note: The number in a column followed by the same letter means that it is not significantly different at the 5% LSD test level.

Evaporation treatment on panicles of sorghum, both the Numbu and Local varieties caused the tannin content to decrease (Table 6). The highest tannin content in the control treatment (without evaporation) was 45.56 mg/100g for the Numbu variety and 141.82 mg/100 g for the Local variety. The lowest tannin content in the 35-minute steaming treatment was 38.12 mg/100 g for the Numbu variety and 135.12 mg/100g for the local variety. Based on the table also shows that the tannin content continued to decrease during storage, namely in the storage of the Numbu variety with 35 minutes of steam treatment in the 0th month of 38.12 mg/100g, the 2nd month of 37.09 mg/100g, and the second month of 37.09 mg/100g. 4 of 36.15 mg/100g. Likewise, local varieties have decreased, such as the Numbu variety with different farmer concentrations.
Table 6. Tannin levels (mg/100g) of Numbu and Local varieties of sorghum during storage. Maros 2018.

| Evaporation time (minutes) | Numbu varieties (month of storage) | Local Varieties (month of storage) |
|----------------------------|------------------------------------|-----------------------------------|
|                            | 0       | 2       | 4       | 0       | 2       | 4       |
| 0                          | 46.56   | 45.12   | 43.45   | 141.82  | 139.79  | 138.08  |
| 15                         | 42.18   | 40.26   | 39.06   | 140.76  | 136.99  | 134.45  |
| 25                         | 39.87   | 38.80   | 37.88   | 137.79  | 133.68  | 131.56  |
| 35                         | 38.12   | 37.09   | 36.15   | 135.12  | 132.09  | 130.12  |

The decreased tannin content has a positive impact, this is because tannins have many benefits as antioxidants. But in high amounts, it is anti-nutritional because it will inhibit the absorption of protein and other nutrients. The tannin content of local varieties of sorghum is much higher than that of the Numbu variety. This can also be seen from the physical appearance of local varieties of sorghum which has a reddish-brown color, while the Numbu variety is white-light brown. A darker red color indicates a higher tannin content. Tannins are polyphenolic compounds, can form complex compounds with proteins, thereby reducing the quality and digestibility of proteins. As supported by [18], tannins are anti-nutritional substances capable of binding to proteins and other microminerals with the main characteristics of binding and precipitating protein, starch, cellulose, pectin, alkaloids, and vitamin B12 [19]. Meanwhile, in low amounts, tannins are beneficial because they have antioxidant [3] and tannins include phenol components that act as antioxidants, can lower LDL, and are antithrombogenic [20, 21, 22] and antimicrobial [18] activities.

3.2. Physical Properties
During storage of sorghum panicles, physical observations were carried out which included analysis of yield loss, by looking at the damaged parts caused by warehouse pests and the smell of sorghum flour every 2 months for 4 months. Based on Table 6 and Table 7 shows that the evaporation treatment on sorghum panicles can maintain its quality to extend the shelf life.

According to research results from [23], steam treatment of hot water on corn seeds will be able to kill microorganisms, because the steam will penetrate the seeds. So the longer the evaporation period, the lower the level of warehouse pest attack on sorghum, both Numbu and local varieties, can be seen from the loss of yield.

Table 7. Yield loss of Numbu & Local varieties of sorghum during storage. Maros 2018.

| Evaporation time (minutes) | Numbu varieties (month of storage) | Local Varieties (month of storage) |
|----------------------------|------------------------------------|-----------------------------------|
|                            | 0       | 2       | 4       | 0       | 2       | 4       |
| 0                          | -       | 31.85   | 35.18   | -       | 20.55   | 26.74   |
| 15                         | -       | -       | 12.09   | -       | -       | 7.78    |
| 25                         | -       | -       | 10.12   | -       | -       | 6.75    |
| 35                         | -       | -       | 9.49    | -       | -       | 6.10    |
Table 8. Results of aroma analysis of Numbu & Local varieties of sorghum flour during storage. Maros 2018.

| Evaporation time (minutes) | Numbu varieties (month of storage) | Local Varieties (month of storage) |
|----------------------------|-----------------------------------|-----------------------------------|
|                            | 0      | 2      | 4      | 0      | 2      | 4      |
| 0                          | Normal | Musty  | Musty  | Musty  | Musty  | Musty  |
| 15                         | Normal | Normal | Normal | Normal | Normal | Normal |
| 25                         | Normal | Normal | Normal | Normal | Normal | Normal |
| 35                         | Normal | Normal | Normal | Normal | Normal | Normal |

In storage of sorghum varieties of Numbu and local varieties that were not given evaporation treatment after being stored for two months were attacked by warehouse pests. This can be seen from the yield loss of 31.85% for the Numbu variety and 20.55% for the local variety. But the nutritional composition is still feasible as a food ingredient, even though the aroma of the flour has a musty smell. The 15 minute steam treatment for the Numbu variety started to show some warehouse pests, but for the local varieties there was no evidence of warehouse pests. According to information from previous research, warehouse pests attack sorghum seeds very quickly compared to corn seeds [24].

Another study related to the decline in the quality of sorghum seeds of several lines/varieties after being stored for several months due to warehouse pests. The Numbu and Kawali varieties have seed shelf life of up to 2-3 months, this is done in the form of sorghum seeds that have been sorted in small quantities with safe storage in small plastic boxes [25]. While in this study stored in the form of panicles without sorting. Informed that the storage of sorghum seeds after sorting treatment in sample storage was relatively small, at four months several varieties showed different levels of damage for Keller 42.7%, Isiap Dorado 22.3%, Keris 58.2%, and Mandau 22.2% [24].

As a reference for the storage of sorghum in the form of flour, it shows a longer shelf life than in the form of seeds. Sorghum flour of Numbu and Kawali varieties stored in plastic bags can last more than six months without being attacked by warehouse pests with a significant decrease in nutritional composition. The shelf life of sorghum flour is also longer than that of corn flour, this is presumably because sorghum flour contains tannins (polyphenol compounds) which are antioxidants that taste apt and may not be liked by warehouse pests [3]. In addition, local varieties of sorghum have a lower yield loss rate of 11.84%, while the Numbu variety is 16.72%. This is because the tannin content in the local variety is higher than the Numbu variety, which can be seen from the red-brown panicle color so that it affects its shelf life.

4. Conclusion

1. Proximate composition including ash, fat, protein, and carbohydrate content at two and four months shelf life for Numbu and Local varieties of sorghum did not show any significant changes including steam treatment for 15 minutes, 25 minutes, and 35 minutes. In contrast to the absence of steam, starting from storage for two months, the moisture content has increased, and has been attacked by warehouse pests causing damage to the seeds so that the nutritional components decrease.

2. Control samples (without steam) of Local and Numbu varieties of sorghum after two months of storage began to be attacked by warehouse pests. For local varieties that have not been attacked by steam treatment for 15 minutes, the nutritional composition is still maintainable and suitable for food. For local varieties up to four months storage.

3. The reduction of the tannin component is an added value of this method of sorghum storage technology, because it is expected that the material of sorghum flour contains very low tannin.
4. The technology of storing sorghum in the form of panicles with the application of hot steam can be applied in sorghum-producing areas, especially during the rainy season. The bath can be modified at the local workshop, with the capacity as needed. After the steam treatment, the sorghum is left to cool in the open.

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