

Physical, chemical and sensory characteristics of bread with different concentrations of acetylated arenga starches

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Abstract

The present work was conducted to determine the effect of acetylated arenga starches (AAS) substitution on the physical, chemical and sensory characteristics of bread. Arenga starch was modified with acetic anhydride to produce AAS. The wheat flour was substituted with AAS at 0, 10, 20, 30, 40, 50 and 60%. The physical properties of bread samples, the chemical composition of wheat flour, AAS and bread samples, and the sensory attributes of breads were investigated using standard procedures. The physical properties of bread samples showed that oil holding capacity, oil absorption and oven spring increased, but solubility decreased with the increasing of AAS. Increasing the substitution from 10% to 60% AAS significantly increased the fat, crude fibre, ash and carbohydrate of the substituted bread samples, while there was a significant decrease in protein value. The sensory analysis showed significant differences in texture and overall acceptability of sensory attributes. It was concluded that a substitution of up to 50% AAS into wheat flour yielded bread with general quality acceptability. Therefore, the AAS has a potential to be used as a substitute for wheat flour.

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Keywords

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Introduction

Bread is a universally accepted form of appropriate foods that is important to all populations. It is a good source of macronutrients (carbohydrate, protein and fat) and micronutrient (minerals and vitamins) which are essentials for human health (Nwokorie and Ezeibe, 2017). In Indonesia, bread is particularly made from wheat. However, wheat cannot be grown locally due to unfavourable climate. Therefore, wheat flour is imported to satisfy flour needs for bread making. Adawiyah *et al.* (2013) have reported that arenga starch was more suitable for making starch doughs than the sago starch because it formed a strong and more resistant gel at concentrations upon the gel point.

Arenga starch is an important source of starch in tropical countries including Indonesia. Arenga (sugar palm) starch is extracted from the sugar palm (*Arenga pinnata*) trees (Rahim *et al.*, 2017) through the pith of the sugar palm trunk (Sahari *et al.*, 2012). Sahari *et al.* (2013) showed that one tree of sugar palm

could produce about 50-100 kg starch. The amylose content of arenga starch is approximately 37.0-37.6% (Rahim *et al.*, 2012a; Adawiyah *et al.*, 2013; Sahari *et al.*, 2014). The use of native arenga starch is limited both for food and non-food applications. Therefore, it requires chemical modification by acetylation to produce acetylated arenga starch. The acetylation of arenga starch promotes the incorporation of acetyl groups in the starch molecule to improve the chemical and functional properties of the modified starches (Rahim *et al.*, 2015).

The acetylation of arenga starch with acetic anhydride at 5 to 20% (of the total starch basis) results in a degree of substitution between 0.033 to 0.249, thereby enabling for food application. Acetylation of the arenga starch molecule decreases the crystallinity and increases the water holding capacity, oil holding capacity, swelling power and solubility along with the increase in substitution degree. The present work will be useful to promote the use of the acetylated arenga starch for industrial applications in food production such as biscuits, noodles and bread (Rahim *et al.*,

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centrifuge tube and weighed (W_1). The bread was then dispersed in 20 mL water. It was then heated at 80°C for 30 min in a thermostat water bath. The mixture was cooled at the room temperature and centrifuged at 3,000 g for 15 min. The supernatant was decanted carefully and the residue was weighed for swelling power determination. The weights of dry centrifuge tube, the residue and the water retained were taken as W_2 . The swelling power was then measured using Eq. 1.

$$\text{Swelling power} = \frac{W_2 - W_1}{\text{dry weight of the bread}} \quad (\text{Eq. 1})$$

For solubility, aliquots (5 mL) of the supernatant were dried to a constant weight at 110°C. The residue obtained after drying represented the amount of bread solubilised in water. Solubility was then calculated as g per 100 g of bread on dry weight basis.

Oil absorption determination

The oil absorption of bread was determined using the procedure described by AOAC (1990) with slight modifications. Briefly, a measured quantity of oil was taken and approximately 5 g bread was dropped in the oil and fried. The amount of oil absorbed by 5 g bread was calculated by the difference in weight of oil before and after frying the bread.

Loaf weight determination

The loaf weight was determined for 30 min after the breads were removed from the oven and the readings were recorded in grams (Makinde and Akinoso, 2014).

Oven spring determination

The oven spring was measured by the difference in height of dough before and after baking (Makinde and Akinoso, 2014).

Moisture content determination

Clean porcelain crucibles were oven dried at 105°C for 2 h, cooled in a desiccator and weighed (W_0). Approximately 2.0 g samples was weighed into the crucibles and the whole crucible with the sample re-weighed (W_1). The crucibles with the samples were oven dried at 105°C for 8 h, and cooled in a desiccator before being re-weighed (W_2). The moisture content was measured using Eq. 2 and expressed as the percentage per gram sample.

$$\% \text{ Moisture} = \frac{W_1 - W_2}{W_1 - W_0} \times 100 \quad (\text{Eq. 2})$$

Protein content determination

The total nitrogen content was determined by the semi-micro Kjeldahl method. Approximately 1.0 g samples with 10 g mixture of potassium sulphate and copper sulphate (100:7) as the catalyst was digested in 25 mL concentrated sulfuric acid at 420°C. After digestion, cooled samples were diluted with 75 mL distilled water, distilled into 1% boric acid and titrated against 0.5 M hydrochloric acid. The bromocresol green and methyl red indicators were used, and changed to a final colour of light pink at the end point of the titration. The percentage of total nitrogen and of crude protein was measured using Eq. 3:

$$\% \text{ Total nitrogen} = \frac{(14.01 \times M \times 100) \times (\text{mL titrant} - \text{mL blank}) \times 100}{\text{mg sample}} \quad (\text{Eq. 3})$$

where 14.01 = atomic weight of nitrogen, and M = molarity of the acid (mol/L).

$$\% \text{ Crude protein} = \text{Total N} \times 6.25 \quad (\text{Eq. 4})$$

Since, on the average, protein contains about 16% nitrogen, one can either divide the percentage of nitrogen by 0.16 or multiply it by a factor of 6.25 to obtain the crude protein content.

Fat content determination

The crude fat content was determined gravimetrically. Approximately 5.0 g samples were used (W_0). The samples were not hydrolysed prior to extraction with ether. The fat was extracted into pre-weighed thimbles (W_1), dried overnight at 105°C, cooled and weighed (W_2). The crude fat content was calculated using Eq. 5:

$$\% \text{ Crude fat} = \frac{W_2 - W_1}{W_0} \times 100 \quad (\text{Eq. 5})$$

Crude fibre content determination

The crude fibre content of the samples was determined by the method of AOAC (1990). Approximately 1.0 g samples (W_0) was weighed into fritted glass crucibles and hydrolysed with boiling 0.128 M sulfuric acid, followed by boiling in 0.223 M potassium hydroxide solution in a hot extractor. The residue was washed with preheated distilled water before being transferred to a cold extractor and washed with acetone. The residue and crucibles were

oven dried at 105°C overnight and weighed (W_1) before being ignited in a muffle furnace at 450°C for 8 h. The residual ash was firstly cooled in an oven at 105°C overnight, then cooled at room temperature in a desiccator and finally weighed (W_2). The percentage of crude fibre in the samples was calculated using Eq. 6:

$$\% \text{ Crude fibre} = \frac{W_1 - W_2}{W_0} \times 100 \quad (\text{Eq. 6})$$

Ash content determination

The ash content was determined using the same samples used in the dry matter determination. After the moisture content of the samples was determined, the samples were ignited in a muffle furnace at 550°C overnight, followed by cooling to room temperature in a desiccator and weighed (W_3). The ash content was calculated using Eq. 7:

$$\% \text{ Total ash} = \frac{W_2 - W_3}{W_1 - W_0} \times 100 \quad (\text{Eq. 7})$$

Carbohydrate content determination

The carbohydrate content was estimated by difference. The crude protein, crude fat and the total ash were subtracted from organic matter, the remainder accounted for carbohydrate as in Eq. 8:

$$\% \text{ Carbohydrate} = 100\% - \% (\text{moisture} + \text{protein} + \text{fat} + \text{ash}) \quad (\text{Eq. 8})$$

Sensory evaluation

The sensory evaluation of bread from AAS was performed following the method described by Larmond (1977) with slight modifications. The sensory analysis of the freshly baked bread samples were performed using 15-member panel consisted of the adult population (students and staff) of the Faculty of Agriculture, Tadulako University, Central Sulawesi Indonesia. The bread samples were sliced into pieces with similar thickness (3 cm), coded with 3-digit random number and served to the panellists with distilled water for rinsing the mouth between each taste in a randomised order. The panellists were asked to evaluate each bread samples for crumb colour, texture, aroma, taste and overall acceptability. A 5-point hedonic scale was used where 1 – dislike very much, 2 – dislike, 3 – neither like nor dislike, 4 – like and 5 – like very much. The panellists were instructed to rate the attributes indicating their degree of liking or disliking by putting a number as provided in the hedonic scale according to their preference.

Statistical analysis

All data obtained were subjected to analysis of variance with SPSS version 17.00. The means of the results were compared with Duncan's multiple test, and the statistical significance was defined at $p \leq 0.05$.

Results and discussion

Raw material characteristics

The chemical composition of wheat flour and AAS is presented in Table 2. The moisture, protein and fat contents of wheat flour were highly comparable to AAS, but the crude fibre, ash and carbohydrate contents of wheat flour were lower than that in AAS. In general, AAS indicated higher levels of crude fibre, ash and carbohydrate as compared to wheat flour. The high carbohydrate content in AAS is important for the stability of sour dough and bread. Owuamanam *et al.* (2015) reported that the ash and carbohydrate of wheat flour, cassava flour and acetylated cassava starch blended at ratio 50:32:15, were higher than 100% wheat flour for composite bread making. Yildiz and Bilgicli (2012) have also reported that the ash and crude fibre of whole buckwheat flour were higher than that of wheat flour.

Table 2. Chemical compositions of wheat flour and acetylated arenga starch.

Ingredient	Wheat flour	Acetylated arenga starch
Moisture (%)	12.02 ± 0.41 ^b	11.76 ± 0.09 ^a
Protein (%)	9.27 ± 0.49 ^b	2.53 ± 0.11 ^a
Fat (%)	1.62 ± 0.47 ^b	1.81 ± 0.08 ^a
Crude fibre (%)	0.57 ± 0.06 ^a	1.58 ± 0.08 ^b
Ash (%)	0.59 ± 0.03 ^a	0.87 ± 0.03 ^b
Carbohydrate (%)	75.89 ± 1.99 ^a	82.46 ± 1.53 ^b

Data are mean ± standard deviation (SD). Values in the same row with different superscript indicate significant difference ($p < 0.05$).

The physical characteristics of the bread

The physical characteristics of the bread from AAS at substitutions of 0, 10, 20, 30, 40, 50 and 60% are presented in Table 3. The result shows that the physical characteristics of the bread had different significance for the oil holding capacity, oil absorption, solubility and oven spring. It was observed that the water holding capacity, swelling power and weight were not significantly different. The oil holding capacity and oil absorption of all AAS based bread were higher than the 100% wheat flour bread and increased as the substitution of wheat flour increased. This might be attributed to the influence of acetyl arenga starch which enhanced binding and absorption capacity more than wheat flour and

Table 3. Physical characteristics of the bread from acetylated arenga starches.

Parameter	Acetylated arenga starches substitution (%)						
	0	10	20	30	40	50	60
Water holding capacity (g/g)	3.05 ± 0.06 ^a	2.93 ± 0.60 ^a	2.98 ± 0.64 ^a	2.71 ± 0.21 ^a	2.62 ± 0.08 ^a	2.39 ± 0.08 ^a	2.66 ± 0.01 ^a
Oil holding capacity (g/g)	1.77 ± 0.02 ^a	2.84 ± 0.35 ^b	2.79 ± 0.33 ^b	2.92 ± 0.14 ^b	3.03 ± 0.11 ^b	3.04 ± 0.18 ^b	3.23 ± 0.04 ^b
Swelling power (g/g)	38.40 ± 0.28 ^a	38.10 ± 0.04 ^a	38.13 ± 0.35 ^a	38.03 ± 0.05 ^a	37.97 ± 0.16 ^a	38.10 ± 0.18 ^a	38.34 ± 0.52 ^a
Solubility (%)	3.55 ± 0.34 ^b	2.80 ± 0.06 ^a	2.78 ± 0.03 ^a	2.65 ± 0.09 ^a	2.64 ± 0.03 ^a	2.53 ± 0.02 ^a	2.47 ± 0.01 ^a
Oil absorption (%)	0.64 ± 0.02 ^a	0.84 ± 0.05 ^b	0.81 ± 0.06 ^b	0.79 ± 0.01 ^b	0.83 ± 0.05 ^b	0.98 ± 0.05 ^c	1.07 ± 0.02 ^d
Weight (g)	36.20 ± 0.14 ^a	36.05 ± 0.99 ^a	36.00 ± 0.35 ^a	36.05 ± 0.57 ^a	35.85 ± 0.57 ^a	36.23 ± 0.11 ^a	35.30 ± 0.14 ^a
Oven spring (cm)	0.85 ± 0.07 ^a	1.06 ± 0.08 ^b	1.07 ± 0.05 ^{bc}	1.18 ± 0.03 ^{cd}	1.22 ± 0.03 ^d	1.24 ± 0.04 ^d	0.99 ± 0.01 ^b

Data are mean ± standard deviation (SD). Values in the same row with different superscript indicate significant difference ($p < 0.05$).

acetylated starch, indicating that its hydrophobicity was higher than that of wheat flour. Rahim *et al.* (2017) reported that the oil holding capacity of AAS was higher than the native arenga starch. Yadav and Patki (2015) indicated that the increased capacity to absorb oil in acetylated chickpea starch could be due to the incorporation of acetyl groups in starch molecules.

The solubility of all AAS-based bread was lower than the 100% wheat flour bread and decreased as the substitution with AAS increased. Rahim *et al.* (2012b) showed that solubility of butyrylated arenga starches were lower than that of native arenga starch. Colussi *et al.* (2015) reported that the acetylated rice starches showed lower solubility as compared to native rice starch. The decrease in solubility of acetylated rice starches could be attributed to the insertion of acetyl groups in the starch molecules that increased hydrophobicity. The oven spring of all AAS-based bread was higher than the 100% wheat flour bread. The oven spring had a significant increase as the blends increased in the amount of AAS up to 50%. The observed increase in oven spring corresponded to the increase in bulk density as the substitution ratio of AAS increased up to 50%. This might be related to the influence of acetyl groups of AAS and gluten reaction in wheat flour that networked the dough structure and trapped escaping gasses, thereby increasing the oven spring.

The chemical characteristics of the bread

The chemical characteristics of breads are presented in Table 4. The analysis of variance on all chemical analysis data shows significant differences between the bread samples. The moisture content of

all AAS-based bread was lower than that of wheat flour, and decreased with an increase in the levels of AAS substitution. The protein content of all AAS-based bread was lower as compared to that of wheat flour, and decreased as the amount AAS substitution increased. This could be explained by the fact that AAS is a poor source for protein. The fat contents of AAS-based breads were higher than that of wheat flour and increased with the increase in AAS additions. This corresponded with the higher oil holding capacity and oil absorption (Table 3).

The fibre content of AAS-based breads were higher as compared to that of wheat flour breads and increased with increasing amount of AAS. The increase in the fibre content could be due to the fact that wheat flour had lower fibre content as compared to AAS. The result also shows that the ash content of AAS-based breads were higher as compared to wheat flour and increased with increasing amount of AAS. The increase in ash content could be attributed to the higher levels of ash in the AAS as compared to the wheat flour. Makinde and Akinoso (2014) reported that both crude fibre and ash contents of the composite bread samples showed an increase as the level of supplementation with sesame flour increased. This was the direct effect of high content of cellulose, hemicelluloses and lignin in sesame flour than in the wheat flour. Šárka *et al.* (2017) reported that the resistant starch from acetylated starch increased with increasing acetylated starch.

The carbohydrate content of all AAS-based breads were higher than that of wheat flour breads. It was clearly observed that the carbohydrate content increased with increasing AAS amount. This could be attributed to the high contents of carbohydrate in

Table 4. Chemical characteristics of the bread from acetylated arenga starches.

Parameter	Acetylated arenga starches substitution (%)						
	0	10	20	30	40	50	60
Moisture (%)	21.21 ± 0.30 ^{ab}	22.54 ± 2.89 ^b	21.46 ± 0.14 ^{ab}	20.50 ± 0.66 ^{ab}	20.22 ± 1.94 ^{ab}	22.10 ± 0.03 ^{ab}	18.88 ± 0.11 ^a
Protein (%)	12.43 ± 0.21 ^d	10.76 ± 0.46 ^c	9.70 ± 0.50 ^{bc}	8.75 ± 0.50 ^b	9.34 ± 1.35 ^{bc}	7.18 ± 0.17 ^a	6.77 ± 0.16 ^a
Fat (%)	6.25 ± 0.33 ^a	6.51 ± 0.24 ^{ab}	6.66 ± 0.22 ^{ab}	6.69 ± 0.11 ^{ab}	7.03 ± 0.28 ^{bc}	7.31 ± 0.18 ^{cd}	7.73 ± 0.03 ^d
Crude fibre (%)	0.71 ± 0.01 ^a	1.00 ± 0.08 ^a	1.46 ± 0.01 ^b	1.57 ± 0.18 ^b	1.89 ± 0.24 ^c	2.02 ± 0.25 ^c	2.14 ± 0.01 ^c
Ash (%)	0.75 ± 0.01 ^a	0.86 ± 0.57 ^b	0.83 ± 0.02 ^b	0.90 ± 0.02 ^b	0.87 ± 0.01 ^b	0.85 ± 0.01 ^b	0.96 ± 0.01 ^c
Carbohydrate (%)	58.11 ± 0.29 ^a	57.47 ± 1.69 ^a	58.65 ± 0.70 ^{ab}	62.23 ± 0.04 ^c	61.68 ± 3.14 ^{bc}	62.08 ± 0.40 ^c	64.93 ± 0.22 ^c

Data are mean ± standard deviation (SD). Values in the same row with different superscript indicate significant difference ($p < 0.05$).

AAS than in wheat flour. Ijah *et al.* (2014) showed that the carbohydrate content of bread increased with addition of potato flour as compared to wheat flour. Similar results were reported by Mongi *et al.* (2011) who investigated the proximate composition of cocoyam-wheat composite breads at different levels of cocoyam flour substitution. The whole wheat bread and cocoyam-composite breads were prepared in 0, 10, 20 and 30% levels of cocoyam flours substitution. The results indicated that the moisture and protein contents decreased significantly while the carbohydrate, crude fibre, and ash contents of the cocoyam-composite breads increased significantly with progressive increase in the cocoyam flour substitution.

Sensory attributes of the bread

The sensory scores of AAS-based breads are shown in Table 5. The result shows that there was no significant difference between the sensory scores of crumb colour, aroma and taste; while texture and overall acceptability significantly differed between AAS-based breads. The statistical similarity in the rating for crumb colour, aroma and taste might be attributed to the use of AAS which were colourless, odourless and tasteless. This might indicate that AAS might not play any sensory role. The scores also indicate that bread baked with 60% AAS was less acceptable as compared to the other blends.

These are similar to the results of Boz and Karaoğlu *et al.* (2013) who reported that the breads produced from various composite flour i.e. malt, *Cephalaria syrica*, rosehip and vital gluten of whole wheat bread had no significant differences between the sensory attributes to crumb colour, crumb grain and aroma. Owuamanam *et al.* (2015) reported that the incorporation of acetylated starch in bread making did not improve its sensory attributes, but contributed to the improvement of the bread structure and shelf stability.

Conclusions

The present work reveals that adding AAS as a component of wheat flour for bread making at substitution levels of 0, 10, 20, 30, 40, 50 and 60% significantly affected oil holding capacity, oil absorption, solubility and oven spring of the resulting breads. The moisture, protein, fat, crude fibre, ash and carbohydrate of all AAS-based bread shows significant differences between the bread samples. Substitution of up to 50% yielded bread with good overall sensory acceptability. The incorporation of AAS in bread making did improve the physical, chemical and sensory characteristics of bread. The findings of the present work had the potential to promote the production and diversification of breads or cookies from acetylated arenga starch.

Table 5. Sensory scores of the bread from acetylated arenga starches.

Parameter	Acetylated arenga starches substitution (%)						
	0	10	20	30	40	50	60
Crumb colour	4.20 ± 0.67 ^a	4.20 ± 0.67 ^a	4.13 ± 0.74 ^a	4.13 ± 0.64 ^a	4.20 ± 0.56 ^a	4.07 ± 0.59 ^a	4.00 ± 0.54 ^a
Texture	4.13 ± 0.52 ^b	4.13 ± 0.35 ^b	4.07 ± 0.70 ^b	4.13 ± 0.51 ^b	4.13 ± 0.35 ^b	4.07 ± 0.59 ^b	3.40 ± 0.63 ^a
Aroma	3.93 ± 0.46 ^a	4.07 ± 0.26 ^a	4.07 ± 0.46 ^a	4.07 ± 0.46 ^a	4.13 ± 0.36 ^a	4.00 ± 0.53 ^a	3.87 ± 0.35 ^a
Taste	4.07 ± 0.46 ^a	4.07 ± 0.70 ^a	4.07 ± 0.45 ^a	4.07 ± 0.45 ^a	4.13 ± 0.52 ^a	4.00 ± 0.38 ^a	4.07 ± 0.49 ^a
Overall acceptability	4.13 ± 0.35 ^b	4.07 ± 0.46 ^b	4.07 ± 0.46 ^b	4.13 ± 0.35 ^b	4.20 ± 0.41 ^b	4.00 ± 0.53 ^b	3.33 ± 0.49 ^a

Data are mean ± standard deviation (SD). Values in the same row with different superscript indicate significant difference ($p < 0.05$).

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