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The effect of modified heat moisture treatment with microwave on physicochemical characteristics of sago starch

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ABSTRACT

Introduction: This study aimed to characterize the physicochemical properties of forage sago starch using a microwave with different moisture content, namely 20%, 25%, and 30%. **Methods:** A randomized non-factorial design was used with four treatment levels, namely native starch, HMT_{MW20}, HMT_{MW25}, and HMT_{MW30}. Furthermore, the analyzed parameters were moisture and ash content, water and oil absorption, swelling power, and solubility. **Results:** The results showed that moisture content of forages (9.35-12.20%) was lower than native starch (13.08%), ash content of sago starch forages (0.15-0.23%) was lower than native sago starch (0.30%), water absorption of HMT_{MW} sago starch (216.19-317.47%) was higher than native sago starch (222.07%). Furthermore, the absorption of HMT_{MW} sago starch oil (189.73-208.40%) was higher than native starch (176.53%), swelling power value of HMT_{MW} sago starch (23.33-31.90%) was relatively lower than native sago starch (33.07%), solubility of HMT_{MW} sago starch (12, 38-18.47%) was relatively lower than native sago starch (21.00%). **Conclusion:** HMT_{MW} with different initial moisture content (20, 25, and 30%) using 40% power for 15 minutes caused changes in the physicochemical properties of sago starch. In addition, higher concentrations of the initial treatment caused an increase in moisture content and water and oil absorption, while ash content, swelling power, and solubility decreased.

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INTRODUCTION

Physicochemical properties, including retrogradation, syneresis, stability, and low paste resistance to changes in pH and temperature, limit the use of native sago starch in the food industry. Native sago starch has several disadvantages when used as a raw material in the food industry. When cooked, starch takes a long time (up to the need for high energy), and the paste formed is stiff and not transparent. In addition, it is too sticky and cannot withstand acid treatment. According to Fajri *et al.* (2016), native sago starch in product manufacturing causes several problems related to retrogradation, syneresis, low stability, and low paste resistance to pH and temperature changes. These weaknesses limit the use of native starch in the food industry. Therefore, modification can be carried out to enhance the physical, chemical, and functional properties of sago starch. Each modification method produces modified starch with different physicochemical properties (Picauly *et al.*, 2017). Heat Moisture Treatment (HMT) modification is a type of physical modification that addresses these issues.

HMT modification can be done by adding a water concentration of less than 35% and heating it above the glass transition temperature but below the gelatinization temperature (Gunaratne & Hoover, 2002). The properties of modified sago starch with HMT slightly differ from the native starch granules, originating from the hilum in the granule center. Moreover, the central part of the granule is an amorphous region susceptible to heat changes during HMT processing (Adebowale *et al.*, 2005). Starch with HMT technology has several advantages, such as increasing heat resistance, mechanical processing, and starch acidity by increasing the gelatinization temperature and reducing granule swelling capacity (Taggart, 2004). In addition, HMT changes the molecular structure of starch, creating a more resistant crystalline structure during gelatinization processes (Singh *et al.*, 2005).

The study by Gunaratne & Hoover (2002), using the HMT method, resulted in physicochemical and functional properties of starch that could be influenced by the type of starch used as raw material and its processing. Regarding raw material properties, some influencing factors include starch source, amylose content, and crystallization process. Meanwhile, the factors that influence processing include moisture content. Watcharatewinkul *et al.* (2009) stated that moisture content during HMT was an important factor that affected physicochemical properties. Adawiyah & Umareta (2014) used the HMT method with 20% moisture content in an autoclave to produce sago noodles. Purwani *et al.* (2006) used HMT-modified sago starch with 25% moisture content to produce sago noodles. In addition, Syafutri *et al.* (2018) showed that using the HMT *Autoclaving-cooling* method on sago starch with 30% moisture content influenced the swelling power and solubility of Bangka sago starch.

Microwave heating has the potential to reduce content in a shorter time and enhance the quality of dried materials (Drouzas *et al.*, 1999). Moreover, conventionally heated starch damages structures more than microwave heating (Muzimbaranda & Tomasik, 1994). Heating in microwave ovens differs from conventional methods. Microwave radiation directs heat to the core of the material, leading to higher temperatures than the surface due to evaporation (Buffler, 1992). According to Pinasthi (2011), microwave heating with HMT modification increased water absorption but decreased crystallinity and granule swelling. Microwave heating is more efficient than conventional methods because it ensures uniform treatment in the material, better heat penetration, and selective absorption (Rajko *et al.*, 1997). In microwave treatment (MT) or MT500 W (40%), the highest value is obtained compared to HMT and AT (Autoclave Treatment) concerning the physicochemical properties of proso millet starch. HMT, AT, and MT significantly increased a mylose content and resistant starch (Zheng *et al.*, 2019). Therefore, this study aimed to characterize the physicochemical properties of HMTMW sago starch with MT under different moisture content.

METHODS

Material

The materials were commercial sago starch (local brand) obtained from the Dian Pertiwi Poka Ambon store.

HMT preparation

Moisture content (%) of starch was analyzed before modification, and the process was as follows: 100 g of starch was poured into distilled water based on the desired moisture content, namely 20% (HMT_{MW20}), 25% (HMT_{MW25}), and 30% (HMT_{MW30}). The amount of distilled water was determined based on the following equation:

$$(100\% - KA1) \times BP1 = (100\% - KA2) \times BP2$$

Note: KA1 = initial moisture content (%db); KA2 = desired moisture content of starch (%db); BP1 = weight of starch at the initial condition; BP2 = weight of starch after reaching KA2.

The weighed starch was placed in a covered Erlenmeyer flask, and distilled water was added based on determining the initial moisture content. Starch was subsequently left in the refrigerator for 12 hours to achieve moisture content uniformity. After achieving uniform moisture content, the starch to be modified was removed and left at room temperature for 2 hours. HMT modification in the microwave was carried out with a heating time of 15 minutes at 40% power, and the mode and heating time were obtained from preliminary studies. Starch was dried for 4 hours at 50ºC, ground using mortar and pestle to ensure uniform size, and sieved through an 80-mesh sieve.

Moisture content test procedure

The crucible was preheated in an oven at 100°C for 1 hour and transferred to a desiccator for 10 minutes to cool down before being weighed. Furthermore, approximately 2 g sample was weighed into the crucible, dried in an oven at 105°C for 4 hours, transferred to a desiccator, cooled down, and weighed again. The crucible and the contents were dried until a constant weight was achieved (AOAC, 2012). The calculation was carried out as follows:

Moisture Content (%) =

Note: Cup weight (g) = W1; Sample weight (g) = W2; Weight of cup and sample after drying (g) = W3

Ash content test procedure

The crucible was first heated for 1 hour in an oven at 100°C and placed in a desiccator to cool for 10 minutes before weighing. Approximately 3 g sample was weighed into the crucible, and the contents were burned using an electric heater until no more smoke was emitted. The sample was ashed in a furnace at 600°C until it turned white-grayish. Subsequently, the crucible was transferred to a desiccator, cooled down, and weighed (AOAC, 2012). The calculation was carried out as follows:

Ash Content (%) =

Note: W1 = Cup weight (g); W2 = Sample weight (g); W3 = Weight of cup and ash (g)

Water absorption test procedure

Starch (0.2 g) was suspended in 4 mL distilled water and vortexed for 1 minute to measure water absorption. The starch suspension was allowed to stand for 10 minutes at room temperature, centrifuged for 15 minutes at 1000 rpm, and the sediment was subsequently weighed (Kim & Huber, 2013). Water absorption was calculated using the following equation:

Water Absorption (%) =
Where: W0 = initial sample weight before treatment (g); W1 = sediment weight (g)

Oil absorption test procedure

In a centrifuge tube, oil (6 mL) was added to the sample (0.5 g) to measure oil absorption. The tube was vortexed for 1 minute, allowed to stand for 30 minutes, and centrifuged for 25 minutes at 3000 rpm. Furthermore, the supernatant was discarded, and the sediment was weighed (Lazou & Krokida, 2010). Oil absorption was calculated using the following equation:

Oil Absorption (%) =
Where: W0 = initial sample weight before treatment (g); W1 = sediment weight (g)

Swelling power test procedure

Starch was dissolved in distilled water (1% w/v) in a known weight (W1) reaction tube. It was subsequently heated in a water bath (Memmert, Germany) to 95°C for 30 minutes and cooled to room temperature (27°C). The starch suspension was centrifuged (Herm, Germany) at 5000 rpm for 15 minutes to separate the residue and supernatant while the residue was weighed (W2) (Adebowale *et al*., 2009). Swelling power of starch (based on dry weight) was determined using the following equation:

Swelling power (g/g) =

Solubility test procedure

A 10 ml aliquot of the supernatant was dried at 110°C until a constant weight was achieved (Adebowale *et al.*, 2009) . The residue after drying the supernatant showed the amount of starch dissolved in water (%):

Solubility (%) =

Data analysis procedures

Physicochemical properties data of Heat Moisture Treatment Microwave (HMT_{MW}) starch were statistically analyzed using non-factorial analysis of variance with Minitab 20 software. A possible effect of treatment on the observed variables should be followed by the Tukey post-hoc test (α = 0.05) for mean separation.

RESULTS AND DISCUSSIONS

Table 1 shows the observation results of native sago and HMT_{MW} sago starch with variations in moisture content, namely HMT_{MW20}, HMT_{MW25}, and HMT_{MW30}, on physicochemical characteristics such as moisture content, ash content, water absorption, oil absorption, swelling power, and solubility.

Table 1. Physicochemical characteristics of native sago starch and HMTMW

Treatment	Moisture content (%)	Ash content (%)	Water absorption (%)	Oil absorption (%)	Swelling power (g/g)	Solubility (%)
Native starch	13.08±0.07a	0.30±0.07a	222.07±3.75b	176.53±10.5c	33.07±0.52a	21.00±1.60a
HMT_{MW20}	9.35±0.36b	0.23±0.03ab	216.19±4.43b	189.73±1.13bc	31.90±2.01a	18.47±1.28ab
HMT_{MW25}	10.66b±0.85b	0.19±0.02b	233.05±12.3b	196.80±0.72ab	28.35±0.81b	15.42±1.87bc
HMT_{MW30}	12.20a±0.51a	0.15±0.03b	317.4±33.0a	208.40±7.0a	23.33±1.50c	12.38±0.82c

Information: HMT = heat moisture treatment; Values followed by the same letter in the same column do not show significant differences based on the Tukey test (α = 0.05).

Moisture content

The moisture content of native and HMT_{MW} sago starches ranged from 9.35 to 13.08%. The initial treatment for HMT had a highly significant effect (P < 0.01) on starch moisture content. HMT_{MW20} treatment resulted in the lowest moisture content at 9.35%, while the highest was observed in native starch at 13.08%. Moisture content for HMTMW ranged from 9.35% to 12.20%, which was relatively lower compared to native sago starch. This result contradicted Picauly *et al.* (2017), where the moisture content of HMT was higher. The difference could be attributed to variations in heating techniques used for HMT modification. According to Sangadji *et al.* (2024), starch heated using the microwave heating method can affect the water content value due to changes in starch structure during microwave heating.

The initial moisture content treatment increased the moisture content for HMT_{MW}. Picauly *et al.* (2017) also reported relatively similar results, where moisture content for HMT increased with the initial moisture content of starch during modification. The heating process for HMT in a closed condition resulted in limited water evaporation, and there was a possibility of water reabsorption by starch. These initial moisture contents led to different final moisture contents of HMTMW sago starch. According to Haryani *et al.* (2015), the increase in moisture content during modification led to the rearrangement of amylose and amylopectin structures, making water more easily absorbed by starch granules. Furthermore, the increase in moisture content could be attributed to the ability of HMTMW sago starch to absorb water.

Ash content

Ash content of HMTMW sago starch ranged from 0.15% to 0.30%. HMTMW30 treatment led to the lowest ash content at 0.15%. The initial moisture content treatment for HMT had a significant effect ($P < 0.05$) on the ash content of HMTMW. The highest ash content was observed in native sago starch at 0.30%, while HMTMW had a lower content. Picauly *et al.* (2017) and Balasubramanian *et al.* (2014) showed relatively similar results for both HMT and HMT pearl millet starch. Heating at high temperatures during modification could damage HMT's minerals, specifically when using microwaves. Gunorubon & Kekpugile (2012) stated that ash content easily degraded at high temperatures. Nadir *et al.* (2015) also mentioned that heating decreased ash content after modification. According to Ambarsari *et al.* (2019), the lower the ash content in starch, the better because it will affect the final color of the product and can affect the level of product stability.

Water absorption

Water absorption values of HMT_{MW} sago starch ranged from 216.19% to 317.47%. The initial moisture content treatment for HMT_{MW} had a highly significant effect ($P < 0.01$) on starch water absorption. HMT_{MW20} treatment resulted in the lowest water absorption at 216.19%, while HMT_{MW30} treatment had the highest at 317.47%. Water absorption for HMT_{MW} relatively increased, consistent with HMT tapioca starch (Pinasthi, 2011), HMT corn starch (Adebowale *et al.*, 2005; Pinasthi, 2011), HMT sorghum starch (Olayinka *et al.*, 2008), and microwave jackfruit seed starch (Nawaz *et al.*, 2018). The increased hydrophilicity led to high water absorption for HMT (Adebowale *et al.*, 2005; Olayinka *et al.*, 2008). According to Kaletunç & Breslauer (2003), the irregular structure made the amorphous region more easily penetrated. In other words, the amylose content affected water absorption. Lu *et al.* (1996) stated that HMT could increase amylose content and degrade amylopectin, consequently leading to more water absorption.

Oil absorption

Oil absorption values of HMT_{MW} sago starch ranged from 176.53% to 208.40%. The initial moisture content treatment for HMT_{MW} had a highly significant effect ($P < 0.01$) on starch oil absorption. HMT_{MW30} treatment resulted in the highest oil absorption at 208.40%, while the lowest absorption was observed in native starch at 176.53%. Oil absorption for HMT $_{MW}$ increased, relatively consistent with modified HMT tapioca and cornstarch (Pinasthi, 2011), microwave jackfruit seed starch (Nawaz *et al.*, 2018), white sorghum starch, and HMT cassava starch (Olayinka *et al.*, 2008; Abraham, 1993). According to Abraham (1993), the presence of a layer with a lipophilic tendency around starch granules formed by HMT resulted in increased oil absorption for modified starch. According to Puspitasari *et al.* (2019), food ingredients with high oil absorption are important in sausage meat products, pancakes, and soup. Oil absorption needs to be controlled when producing a product because if it is too high, it can also result in a product that is too oily, affecting the flavor or mouthfeel. According to Ghavidel & Prakash (2006), oil absorption is important because it can strengthen flavor and mouthfeel.

Swelling power

The swelling power of HMT_{MW} sago starch ranged from 23.33 to 33.07 g/g. Furthermore, the initial moisture content treatment significantly affected starch swelling power ($P < 0.01$). HMT_{MW30} treatment resulted in the lowest swelling power value at 23.33 g/g, while native sago starch had a 33.07 g/g value. Swelling power for HMT_{MW} relatively decreased. Picauly *et al.* (2017) also reported similar results for HMT, and Adebowale *et al.* (2005) reported for red sorghum and thin sorghum starch (Singh *et al.*, 2009). The decrease in starch swelling power caused by the HMT process could alter starch granule structure, specifically the interaction between crystalline matrixes that interact amorphously. HMT modification resulted in amylose molecules in the amorphous regions interacting with the branches of amylopectin molecules (Picauly *et al.*, 2017). Similar effects were also observed in HMT jackfruit seeds, namely a decrease in swelling power (Sadirman *et al.*, 2020). According to Adebowale *et al.* (2015), the swelling power decreased due to changes in the starch crystalline arrangement and the relationships between starch components on the amorphous side during modification. The increase in the interaction of amylose chains was caused by the transformation of amorphous amylose into helices. Furthermore, the HMT process resulted in denser granule molecules, making swelling difficult due to limited moisture content (Ramdhan & Kurnia, 2009).

Solubility

Solubility of native and HMT_{MW} sago starches ranged from 12.38% to 21.00%. The initial moisture content treatment for HMT_{MW} had a highly significant effect ($P < 0.01$) on starch solubility. The native starch treatment resulted in the highest solubility at 21.00%, while the lowest was observed in the HMT_{MW30} treatment at 12.38%. The solubility of modified HMT_{MW} sago starch relatively decreased. This was consistent with studies on HMT sorghum starch by Olayinka *et al.* (2008), microwave banana starch (Babu *et al.*, 2018), and HMT rice starch (Zavareze *et al.*, 2010). Additional interactions between amylose-amylose and amylose-amylopectin cause a decrease in solubility during the HMT process, which also helped reduce granule swelling (Hoover & Vasanthan, 1994; Olayinka *et al.*, 2008). Olayinka *et al.* (2008) added that several amylose-lipid complexes were crucial in reducing swelling power and solubility.

CONCLUSION

In conclusion, HMT_{MW} treatment with different initial moisture content levels (20%, 25%, and 30%) using 40% power for 15 minutes caused changes in the physicochemical properties of sago starch. Moreover, the increase in the initial moisture content treatment concentration led to some properties of HMT_{MW} sago starch, such as moisture content, water, and oil absorption, to increase, with a decrease in ash content, swelling power, and solubility.

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