GSC Advanced Research and Reviews

eISSN: 2582-4597 CODEN (USA): GARRC2

Cross Ref DOI: 10.30574/gscarr

Journal homepage: https://gsconlinepress.com/journals/gscarr/

(Research Article)

Functional properties and nutritional values of starch from three upland rice varieties (B22, Fofifa 159, 3737) from the middle west of Madagascar

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GSC Advanced Research and Reviews, 2022, 12(03), 145–152

Publication history: Received on 14 May 2022; revised on 23 June 2022; accepted on 25 June 2022

Article DOI: https://doi.org/10.30574/gscarr.2022.12.3.0158

Abstract

This research focused on the study of some functional properties (swelling and viscosity) and nutritional values of three upland rice starches: B22, Fofifa 159 and 3737, from the Middle Western region of Madagascar. The production of upland rice is used to supplement irrigated rice cultivation, and can replace it when producers do not have enough land. The rice starches studied presented some different appearances: white color for B22, white turning yellow for Fofifa 159 and cream for 3737. The touch (tender and light), taste (bland) and odor (non-existent) were similar. The results showed that the starch of the Fofifa 159 variety had the maximum swelling power. The use of the Brookfield RV viscometer made it possible to determine the viscosity of the starch, which is related to the thickening property. The starch from Fofifa 159 had the highest viscosity (80cP) at 90 ° C, compared to the other two samples. The results of the nutritional analysis showed different levels of protein, fat and ash for the three starches of the rice varieties studied. Total protein levels varied between 0.25 and 0.40%, lipids ranged from 0.79 to 1.02%, and ash from 0.42 to 0.54%. The total carbohydrate content was very high, ranging from 98.17 to 98.31% of the dry matter. The corresponding energy values were high and ranged from 401.79 to 403.42 kcal.

Keywords: *Oryza sativa*; Swelling Power; Viscosity; Madagascar

1. Introduction

Rice is the most important cereal crop in the world and is considered as the staple food of more than half of the world's population. In Madagascar, "rice is life" because it is the main food of Malagasy people, with a considerable consumption, around 230,000 tons per month; paddy production was estimated at around 3,9 million tons in 2018-2019 [1]. The annual consumption was estimated at 103 kilograms / person / year between 2010 and 2013 [2]. Madagascar is thus one of the main rice consuming countries in the world. In addition, rice porridge is the most common weaning food used by Malagasy mothers. The diet of Malagasy people is in fact classified as "rice cereal type", with 63.1% of the total energy intake provided mainly by rice [3]. The increase in rice production may contribute to the improvement of food security in Madagascar.

Upland rice varieties are less consumed than irrigated rice varieties, and its production serves to supplement that of irrigated rice, and to replace it when producers do not have enough land to practice irrigated rice cultivation. Some regions of Madagascar tend to lack culture areas, thus new varieties of upland rice, more resistant to altitude and cold, are being developed by researchers. Previous studies have found that upland rice is considered as rich in protein as irrigated rice [4]. Moreover, concerning purchase criteria (such as the absence of sound dust, less breakage, less defect, etc.), upland rice appears to be of superior quality according to Malagasy consumers [5] because, those criteria influence

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consumer preference [6]. From an economic and management point of view, upland cultivation has the advantage of not requiring a costly development unlike irrigated crops or the exploitation of lowlands [7]. This is a possible path for increasing rice production in Madagascar in a situation of saturation of traditional rice growing areas.

Works and research on the characterization of upland rice starch are still scarce, but the qualities possessed by upland rice deserve further research on its starch, knowing that it is its main component. This research focused on the study of the functional properties and nutritional values of upland rice starch belonging to 3 varieties: B22, 3737 and Fofifa 159, with specific objectives: the determination of the swelling power and viscosity, and the nutritional analysis of these upland rice starches. The work was part of the research carried out by LABASAN (Laboratory of Biochemistry Applied to Food Sciences and Nutrition (University of Antananarivo)), on the valorization of Malagasy natural resources in order to contribute to food self-sufficiency, and the fight against malnutrition.

2. Material and methods

2.1. Sampling

The study involved three (3) upland rice samples (Species and genus: *Oriza sativa*), collected in paddy form from Fofifa in Kianjasoa Tsiroanomandidy (Middle West Region of Madagascar). FOFIFA (Foibem-pirenena ho an'ny Fikarohana ampiharina ho Fampandrosoana ny eny Ambanivohita (Center for Applied Research in Rural Development)) is a national laboratory involved in the selection of varieties of rice to be consumed by Malagasy households.

- Sample 1: name: Fotsiambo, collection number: B22;
- Sample 2: name: Fofifa 159, Mahasoa; collection Number: 4178;
- Sample 3: name: Teloriana, collection number: 3737.

2.2. Starch extraction

Starch was extracted from the previously sampled rice grain with a coefficient of variation between 1.86 and 5%, less than 10%. The samples were homogeneous.The rice was reduced to flour (using Black and Decker BX 360-B5 TYPE 2 mixer), then the starch was extracted using a wet extraction method according to the method of Banks and Greenwood [8].

25g of rice flour are soaked in 100 ml distilled water and left to decant for 24 hour. After filtration, the filtrate obtained was centrifuged for 15 minutes at 4000 revolutions / minute and the supernatant was decanted. The pellet was then recovered and placed in the solar dryer for 3 days. Dried products were sieved with a small mesh sieve (0.5 mm in diameter). Simple description of the sample using only naked eyes and simple sensory analysis (scoring scale 1 to 9) [9] was done.

2.3. Swelling power

The swelling indicates the degree of water absorption of the starch granules [10]. Starch swelling is characterized by water absorption which causes the grain to increase in volume, even until it bursts, at different temperatures. The swelling power of starch is determined by increasing temperature. A 1% (weight/volume) starch solution was prepared and placed in a water bath at different temperatures ranging from 50 ° C to 90 ° C with intervals of 10 ° C according to the method of Leach et al. [11]. The mixture was stirred at the maximum for 5 minutes with a vortex, and then centrifuged at 4000 revolutions per min for 10 min. The swelling was estimated by the amount of water retained by the sample by making the dry matter on the pellet (2 h at 130 ° C) in an oven. The pellets recovered after centrifugation were weighed and then dried. The dried pellets were then weighed. The rate of swelling is given by the following formula:

$$Swelling\ Power\ (SP) = \frac{(M0 - M1)}{M1} \times 100$$

Where: M_0 = Mass of the wet base, M_1 = Mass of the dry base

2.4. Viscosity

The viscosity was determined using the Brookfield RV viscometer, model VISCO STAR R, which works by the principle of rotation of a (mobile) cylinder immersed in the material to be tested, while measuring the torsional force necessary to overcome the resistance due to viscosity. For a measuring system (viscometer + mobile) and a given rotational speed (Revolutions per minute: rpm), the viscosity of the liquid is equal to the percentage of the torsion scale multiplied by a factor. An 8% starch suspension was used, which was placed in a water bath at different temperatures ranging from 50 ° C to 90 ° C with intervals of 10 ° C. The starch suspension in a beaker was immersed in the water bath at a desired temperature for 10 minutes. The mobile R2 of the viscometer was used and the apparatus was adjusted to 100 rpm. Then the value on the screen was multiplied by the corresponding factor (for 100 rpm, the factor is equal to four (4)).

2.5. Moisture content

The moisture content was obtained by drying the sample in an oven at 130 ° C for 4 hours, until a practically constant mass was obtained [12].

2.6. Dosage of starch

The Ewers polarimetric method was used to determine the starch content in the samples [13]. The starch was dispersed by the treatment of the sample at a high temperature with dilute hydrochloric acid. After defecation and filtration of the suspension, the optical rotation of the solution was measured by polarimetry. The same treatment was carried using a 40% ethanolic extract; the extraction aimed to remove soluble carbohydrates capable of interfering during the polarimetry. The difference obtained between two polarimetric measurements multiplied by a factor specific to the botanical origin of the starch led to the starch content of the sample.

2.7. Protein content

It is the mineralization of starch by sulfuric acid in the presence of a catalyst followed by alkalinization of the reaction products, and finally a distillation and titration of the ammonia released [14]. The total protein content was determined from the total nitrogen content according to the Kjeldhal method, by multiplying by a conversion factor: 5.95.

0,30 grams of starch was weighed into a digestion flask and 0.70 g of catalyst (copper sulphate and potassium sulphate) was added. Ten (10) ml of concentrated H2SO4 (34N) was added and the flask was shaken to mix the contents. The flask was then placed on a digestion burner for 8 h. First, a gentle heating was applied until the carbonization of starch and the disappearance of the foam, and then an intense heating until the solution turned clear. The sample solution was then transferred into a 100 ml volumetric flask and made up to the mark with distilled water.

Ten milliliters (10 ml) of 4% boric acid was pipetted into a 250 ml conical flask and three drops of Tashiro (Indicator) were added; and 15 ml of 30% NaOH solution were added into the decomposition chamber of the distillation apparatus. Ten milliliters (10 ml) of the digested sample solution was then introduced into a Kjedahl flask. The condenser tip of the distillation apparatus was then dipped into the boric acid contained in the conical flask. The ammonia in the sample solution was then distilled into the boric acid until it changed completely to bluish green. The distillate was then titrated with 0.1 N HCl solutions until it became colorless. The percent total nitrogen and crude protein were calculated using a conversion factor of 5.95.

2.8. Lipid content

This is a method of extracting the sample in the Soxhlet apparatus with hexane to obtain the lipid extract which is soluble in organic solvents [15]. A cartridge filled with 10 g of starch was introduced into the Soxhet apparatus which was connected to a flask containing a few glass beads and whose weight was known. The hexane was then poured into the flask. The extraction process took place at a temperature of 50°C and lasted at least for 12 hours. The solvent was removed by evaporation at 50°C. To determine the fat content of the sample, the flask was reweighed at the end of the evaporation.

2.9. Ash content

Crude ash is the residue obtained after incineration at 550 ° C of the sample of known weight in an electrically heated muffle furnace until a constant mass is obtained, which represents the mineral fraction of the sample [16].

2.10. Total of carbohydrate content

The total carbohydrate content was obtained by the difference between the dry extract content 100 and the sum of the protein, fat and ash contents as a percentage of dry matter [17,18]. The total carbohydrate content was obtained by subtracting the sum of the protein, fat and crude ash content from 100g of dry matter, as showed below.

$$\boldsymbol{CT} = \mathbf{100} - (\boldsymbol{L}\% + \boldsymbol{P}\% + \boldsymbol{A}\%)$$

Where: CT= Total carbohydrate content per 100 g of dry matter; L% = Lipid content per 100 g of dry matter; P% = Protein content per 100 g of dry matter; C% = Crude ash content per 100 g of dry matter.

2.11. Determination of total calorific values

The energy values were calculated according to the recommendation of Southgate and Greenfield [19] using the Atwater coefficients which take into account the digestibility.

2.12. Statistical analysis

All determinations were done in triplicates. Descriptive statistics and analysis of variance (ANOVA) were done using software Minitab 19.1. The difference between means was significant when the p-value < 0.05.

3. Results and discussion

Figure 1 shows the swelling power of the 3 varieties at different temperatures.

The course of swelling was gradual. Like the result reported by Thiranusornkij et al. (2018) [20], swelling power increased with the temperature from 50°C to 95°C. It was low between 50 and 60 ° C. The rate of swelling was similar for all 3 starches. Between 50 and 60 ° C, a small difference not significant (p>0,05) was noticed for the rate of swelling of the 3 samples. The difference was significant (p<0,05) between 60 and 80 ° C, Fofifa 159 had the highest rate, and from 80 ° C the swelling increased considerably. At 90 ° C the starch of the Fofifa 159 variety had a swelling power of 28.29 g of water / g of starch, which is slightly lower than the values found by Ashogbon and Akintao [21], during the study of upland rice starches from Nigeria with swelling values ranging from 24 to 32 g of water / g of starch at 95 ° C. Using other varieties, Lii et al. [22] have found a swelling power ranging from 23 to 30g of water / g of starch at 95 ° C. Lower value have been reported by Abera et al. [23] from popular varieties of upland rice from Ethiopia. Lii et al. [22] have reported that rice starch having the lower amylose composition had a higher swelling power.

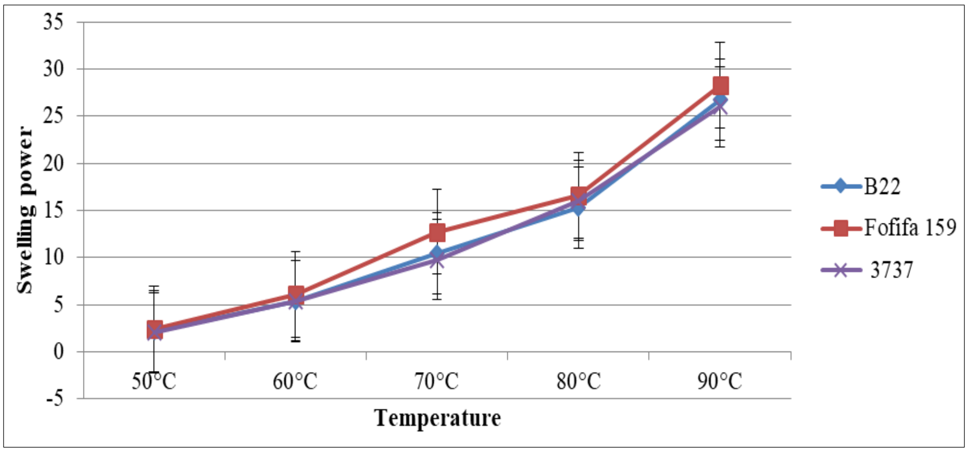

Figure 1 Swelling power of 3 upland rice varieties

According to Rahanitrarivony [4], B22 has a low amylose rate (12.30%), while it has a swelling rate fairly close to 3737 which has 19.70% amylose, by the same shape of the curve swelling. High gelatinization temperature is uncommon, especially when rice starch has a high amylose rate. Low ambient temperature during ripening can increase the amylose content and independently reduce the gelatinization temperature of starch [24]. The difference in swelling power between varieties can be attributed to the difference in amylose composition [25,26]. Low amounts of amylose may increase the swelling power because the granular structure is less rigid [27].

Figure 2 shows the apparent viscosity of the 3 varieties of upland rice.

Indeed, the calculations carried out inside the viscometer from the measurements of the torsional force, the speed of the axis, the angle of deviation of the axis and its characteristics, gave a direct reading of viscosity in centipoise (cP = mPas). The viscosity rose gradually. The shapes of the 3 curves were similar. Between 60 and 80 ° C, the viscosity increased slightly. It increased more significantly after 80 ° C, to reach final viscosities: 68, 72 and 80 mPas. The viscosity of starch of Fofifa 159 was significantly different between (p<0,05) 70 and 80 ° C compared to the other varieties. The increase in viscosity with the temperature could be attributed to the departure of water with exudation of amylose from the granule as the grain swells [28]. The difference in swelling and viscosity property between starches is attributed to the variation of the distribution of length amylopectin [26].

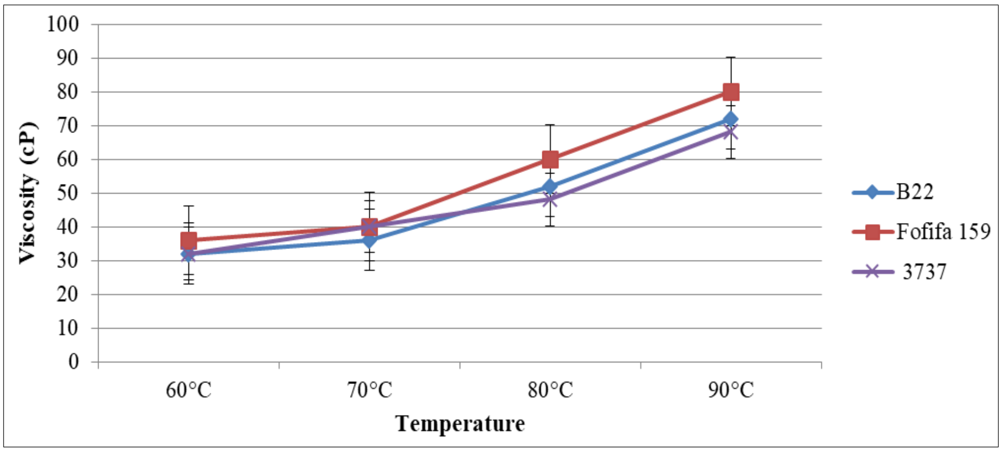

Figure 2 Viscosity of starch of 3 upland rice varieties

3.1. Nutritional analysis

The results of the nutritional analysis are presented in Table 1. For this study, the moisture of the flour ranged from 11.5 to 15%. B22 and Fofifa 159 had a higher moisture rate than 3737 and the difference was significant (p<0,05). Compare to other popular rice varieties which are reported by several authors, the results are nearly similar. Sholehah et al. [29] have found 10.8 to 13% of water content in Indonesian aromatic rice cultivars; Verma and Srivastav [30] reported also similar results. According to the alimentarus codex and other researcher, the water content should not exceed 15% [30,31], for good storage. Lower water content may be required for certain destinations, taking into account the climate, the duration of transport and the storage.

Table 1 Nutritional value of 3 upland rice varieties (100g of dry matter (DM))

	B22	**Fofifa 159**	**3737**
Moisture (%)	14(±1,40)[a]	15(±0,35)[a]	11,5(±2,6)[b]
Protein (%)	0,24(±0,27)[a]	0,11(±0,78)[b]	0,29(±0,45)[c]
Lipid (%)	0,8(±0,17) [a]	1,02(±0,02)[b]	0,98(±0,08)[b]
Ash (%)	0,54(±0,02)[a]	0,42(±0,09)[b]	0,52(±0,04)[a]
Carbohydrate (%)	98,42(±1,05)[a]	98,45(±1,16)[a]	98,21(±1,28)[a]
Starch (%)	75,34(±2,11)[a]	76, (±1,98)[a]	79,83(±1,67)[c]
Moisture of Starch (%)	11,54(±1,25)[a]	12,3(±1,46)[a]	10,74(±1,18)[c]

Values are mean ± standard deviations of triplicate determinations. Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance (p>0,05)

The starch content in rice flour for this study varied from 75.34g to 79.83g per 100g of dry matter. The variety 3737 had a higher starch rate, and compared to those of B22 and Fofifa 123, the values were significantly different (p<0,05). Adwita Arsa et al. [32] have reported a comparable result with five upland rice varieties from Indonesia. Li et al [33] have found that the major component in rice flour is starch: 90% as a percentage of the dry matter, along with other varieties of rice. Zhao et al. [34] reported starch content of some popular rice varieties (Long rice, Australian Wild Rice, Sushi, etc.) raged from 75,9 to 74,4% which is comparable with the results of this work. Nonetheless, according to Kraithong and Rawdkuen [35] some rice varieties have a less starch rate (less than 70%) due to the presence of other contents in higher levels.

Shown in Figures 3, 4 and 5, the three varieties studied rice starches had different color appearances: 3737 cream, Fofifa 159 white turning yellow and B22 is white. The color of the starch may be influenced by the cleanliness, the mode of extraction and the processes of the rice from which the starch is derived, and on the other hand it may also be influenced by the rice variety [36]. The touch (tender and light), taste (bland) and smell (non-existent) were similar for the 3 starches, not significantly different.

Figure 3 Sample 1 – B22

Figure 4 Sample 2 – 159

Figure 5 Sample 3 – 3737

The starch of these studied rice varieties has a moisture content ranging from 11.54 to 12.3%. Only 3737 was significantly different from the other varieties ($p<0,05$). This result is consistent with the values found by Ashongbon and Akintao [21] with rice starch from upland rice varieties from Nigeria (Igbemorice, EfonAlayerice): between 10.40 and 12.77%. The small variation in the moisture of rice starch could be attributed to the difference in cultivar [26,37], and also to the differences in the way the farmer handled the rice [32].

The total protein contents of these rice varieties ranged from 0.11 to 0.29% in 100g of dry matter. All values were different significantly ($p<0,05$). Starch from upland rice in Nigeria has protein content less than 0.43% [21]. The total protein content of other varieties of rice is around 0.25% ;[38].

Concerning the fat rate of starch from the free rice varieties, B22 had the lowest rate (0.8%) and Fofifa 159 had the highest value (1.02%). The values were not significantly different for Fofifa 159 and 3737, but that of B22 was significantly lower than the other varieties. This result is consistent with previous work by Ashogbon and Akintao [21] with upland rice starch from Nigeria: 1% fat per 100g dry matter. The lipid content, even a minority compared to the total starch composition, should not be neglected since it can disturb the swelling power and the solubility of the starch grain [39]. Starch lipids are mainly monoacyl lipids (fatty acids and lysophosphatides) associated with amylose [40]. The starch lipid content is the lowest for glutinous rice starch granules (≤ 0.2%) and highest for rice with intermediate amylose content (1.0%); it is perhaps slightly lower for rice rich in amylose [40,41].

The raw ash contents varied from 0.42 to 0.54%. Only Fofifa 159 had an ash content significantly different compared to the other varieties. This result is consistent with the values reported by Kraithong and Rawdkuen [34], between 0.3 to 1.8%, concerning starches of other varieties. Compared to the values found by Ashogbon and Akintao [21], ranging from 0.2 to 0.24%, the results obtained from this work are significantly higher. According to Murningsih et al. [42], the amount of ash content reflects the amount of the total mineral content.

The total carbohydrates represent almost all the dry matter of the rice starch. That is why other components are in small quantity. Statistically, the amount of carbohydrate in the three varieties were not significantly different ($p>0,05$).

4. Conclusion

The present study confirmed that the three varieties of rice studied have different functional characteristics; the variety Fofifa 159 has the highest swelling and viscosity values. Little work has been done on the nutritional value and functional property of rice starch in Madagascar. However, given the nutritional and energy value and their thickening properties, it is possible to use them as a base or additive in infant food formulations.

Compliance with ethical standards

Acknowledgments

The authors would like to thank the LABASAN ((Biochemistry laboratory applied to food science and nutrition), University of Antananarivo, Madagascar) and FOFIFA (National Agricultural Research Center of Madagascar) for their contribution.

Disclosure of conflict of interest

The authors declare that there are no competing interests related to this work.

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