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Influence of Experimental Conditions and Size on Water Absorption Capacity and Water Solubility Index of Cassava Root Starch (*Manhiot esculenta Cranz*) cv Bonoua 2

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The general objective of this work is to provide useful information to the scientific world on the extrinsic physical factors of starches which could influence the determination of the water absorption capacity and the water solubility index in order to help them to properly assess the industrial qualities of foods. It therefore consisted in varying the solvent, the incubation temperature, the centrifugation time and the concentration of the starch in the reaction medium during the determination of the water absorption capacity and the solubility index in the water according to the granulometry of the cassava starch *Manhiot esculenta* cv Bonoua 2. Particles whose sizes are less than 250 µm are the most represented in the total dry ground of cassava root *Manhiot esculenta* cv Bonoua 2. The water absorption capacity and the water solubility index vary significantly ($p<0.05$) depending on the particle size and the détermination parameters. Tap water decreases the water absorption capacity while it increases the water solubility index. At incubation temperatures above 55 ° C, the water absorption capacity and the water solubility index increase considerably. The centrifugation time greater than 10 min at a speed of 5000 rpm leads to a decrease in the water absorption capacity but promotes an increase in the water solubility index. The water absorption capacity increases with the concentration of starch, while the water solubility index decreases with the increase in the concentration of starch.

Introduction

Cassava is an important source of starch, and flour. Indeed, several studies have shown that cassava bread starch has contributed considerably to the cassava industrial revolution, mainly in Nigeria and Ghana (Sanni *et al*, 2006), and offers enormous potential in the other countries of the sub-region. -region. The product has been found to be suitable for making cakes, cookies, donuts and breads, whether or not added to other flour, as well as main courses (Amani and Kamenan, 2003). The transformation of cassava tubers into bread starch, as the primary processing of cassava, represents an asset for initiating industrialization in rural areas, increasing the market value of cassava and improving the income of producers and, consequently, their conditions of life.

However, for a better industrial use and an adequate valuation of cassava starch, it is essential to master its physico-functional properties. Physico-functional properties are a set of physicochemical and organoleptic properties, determining the structure, technological quality, nutritional quality and acceptability of a product (Moure *et al.*, 2006).

They represent the parameters that determine the application and end use in the industry of flour, starch and starch for the manufacture of various food products. Among these physico-functional properties, we can cite: the water absorption capacity, the water solubility index, the dispersibility, the wettability, the swelling power, the foaming capacity, the stability of the foam, emulsification and gelation properties, bulk density, porosity, retrogradation and viscosity (Yu *et al.,* 2007).

The factors that influence the physico-functional properties of starches are well known to the scientific world because they have been the subject of numerous studies (Sasaki and Matsuki, 1998; Peroni *et al.*, 2006; Njintang *et al.*, 2007). On the other hand, those concerning the physical parameters involved in the methods of measuring these physico-functional properties have most often been ignored. These are the mass of the sample taken, the volume and type of solvent used for measurement, the volume of the test tube and the centrifuge tube, the temperature and time of incubation, speed, time and time centrifugation temperature, time and force of homogenization, particle size, temperature and time of storage of the sample in the refrigerator and freezer, the type of device used. Could these physical parameters not significantly affect the physico-functional properties of starches and mislead researchers and manufacturers in the assessment of their industrial quality?

The general objective of this work is therefore to provide useful information on those extrinsic physical factors of starch which could influence the determination of the water absorption capacity and the water solubility index in order to help those - here to properly assess the industrial qualities of food. The starches used were those of the manioc root *Manhiot esculenta*Crantz cv Bonoua 2.

They were obtained by particle size separation from the total dry ground material. The work consisted of studying the influence of the experimental and particle size conditions on the water absorption capacity and the water solubility index of the starches of the cassava root *Manhiot esculenta* Crantz cv Bonoua 2.

Materials and Methods

Biological material

The biological material used in this work was the tuberous root of the manioc *Manhiot esculenta* cultivar Bonoua 2. It was harvested at 12 months of physiological maturity, on our experimental plot located on the North highway, 44 kilometers from Abidjan (Côte d'Ivoire).

The biological material was transported on the day of harvest to the Laboratory of Biocatalysis and Bioprocesses of the Training and Research Unit in Food Science and Technology of NANGUI ABROGOUA University for the various analyzes.

II-Methods

Production of starch from cassava root *Manhiot esculenta* cv Bonoua 2 depending on the grain size

The roots of the *Manhiot esculenta* cv Bonoua 2 cassava were peeled with a stainless steel knife, cut into large pieces, then washed thoroughly in distilled water. These pieces were cut into strips using a manual grater on aluminum foil. These coverslips were spread out on aluminum foil and then dried in a ventilated oven of the Memmertr brand at 45 ° C. for 72 hours. After drying, the coverslips were ground using a Moulinex type electric mixer. The ground material obtained was sieved using an AFNOR sieve column of different 750, 500 and 250 µm mesh or left as it was (Figure 1). The four starches obtained were stored in tightly closed bottles and stored in a desiccator until use.

Influence of the experimental conditions on the water absorption capacity and the water solubility index of the starches of the cassava root *Manhiot esculenta* Crantz cv Bonoua

Standard conditions

The water absorption capacity and the water solubility index of cassava root starch *Manhiot esculenta* Crantz cv Bonoua 2 were determined respectively according to the methods of Phillips *et al.,* (1988) and Anderson *et al.,* (1969). One (1) g of starch was dissolved in a centrifuge tube containing 10 ml of distilled water. This mixture was stirred for 30 min by a mechanical stirrer of the Rotatern brand and then kept in a water bath at 37 ° C. for 30 min. It was then centrifuged at 5000 rpm for 15 min in a centrifuge. The pellet obtained was weighed using a balance, then dried at 105°C in an oven to a constant mass. The water absorption capacity and the water solubility index of the starch were calculated from the following mathematical relationships:

$$CAE\ (\%) = \frac{M_2 - M_1}{M_1} \times 100 \qquad ISE\ (\%) = \frac{M_0 - M_1}{M_0} \times 100$$

CAE: Water absorption capacity (%);
ISE: Water solubility index (%)
M0: Mass (g) of starch;
M1: Mass (g) of the dried pellet;
M2: Mass (g) of the wet base

Influence of the solvent

The influence of water type on the water absorption capacity and the water solubility index of cassava root starch *Manhiot esculenta* Crantz cv Bonoua 2 was determined under standard conditions (Phillips *et al.*(1988); Anderson *et al.,* (1969)), only that the distilled water solvent was replaced by tap water.

Influence of the incubation temperature

The influence of the incubation temperature on the water absorption capacity and the water solubility index of the starches of the cassava root *Manhiot esculenta* Crantz cv Bonoua 2 was studied under standard conditions (Phillips *et al.,* 1988; Anderson *et al.,* 1969) by varying the incubation temperature from 30 to 65°C.

Influence of centrifugation time

The influence of the centrifugation time on the water absorption capacity and the water solubility index of the starches of the cassava root *Manhiot esculenta* Crantz cv Bonoua 2 was determined under standard conditions (Phillips *et al.,* 1988; Anderson *et al.,* 1969) by varying the centrifugation time from 10 to 30 min.

Influence of starch concentration

The influence of the starch concentration on the water absorption capacity and the water solubility index of the starch of the cassava root *Manhiot esculenta* Crantz cv Bonoua 2 was studied under standard conditions (Phillips *et al.,* 1988; Anderson *et al.,* 1969) by varying the starch concentration from 5 to 20%.

Statistical processing

Statistical analyzes were performed on 4 samples with 3 replicates for each sample. STATISTICA 7.1 software was used for these analyzes.

Duncan's statistical test was used for comparison of means. It established the variability within the different samples analyzed and the statistical significance was defined at $p < 0.05$.

Results and Discussion

Particle size study of the total dry ground of the cassava root *Manhiot esculenta* Crantz cv Bonoua 2

For 100 g of total dry ground of the cassava root *Manhiot esculenta* Crantz cv Bonoua 2, different masses of starch according to the grain size are obtained. Starches are named M0 (grain size <250 µm), M1 (250 µm <grain size <500 µm) and M2 (500 µm <grain size <750 µm).

The respective masses are 46.95 ± 0.07 g, 17.85 ± 0.21 g and 29.52 ± 0.45 g. Statistical analysis revealed that these starch masses were significantly different from each other at $p < 0.05$ according to Duncan's test. M0 starch, which is the finest starch, is the most represented in the total dry ground material (Figure 2).

Influence of the experimental conditions and of the particle size distribution on the water absorption capacity and the water solubility index of the starch from the root of manioc *Manhiot esculenta* Crantz cv Bonoua 2

Water absorption capacity

Influence of the solvent

The water absorption capacities of the four starches of the cassava studied vary significantly ($p < 0.05$) according to Duncan's test when distilled water and tap water are used as solvents (Figure 3). They are respectively for starches MO, M1, M2 and NT when distilled water is used as a solvent of 144.85 ± 4.76%, 152.55 ± 3.07%, 162.46 ± 9.56% and 147.37 ± 14.45 %. By replacing distilled water with tap water, the water absorption capacities obtained from starches M0, M1, M2 and NT are respectively 142.82 ± 0.79%, 145.90 ± 0.79 %, 146.84 ± 1.14% and 140.54 ± 1.68% (Figure 3). Tap water significantly ($p < 0.05$) decreases the water absorption capacity. This physico-functional parameter is also a function of the grain size of the starch (Figure 3).

Influence of the incubation temperature

The increase in the incubation temperature during the determination of the water absorption capacity of the starch of the cassava root allowed to improve significantly ($p < 0.05$) this physico-functional parameter at temperatures above 50 ° C. The maximum values are reached at 65 ° C for the temperatures studied and vary from 571.99 ± 0.40% to 659.19 ± 1.06%. The incubation temperature significantly ($p < 0.05$) influences the water absorption capacity from 55 ° C. The increase in water absorption capacity is a function of particle size (Figure 4).

Influence of the centrifugation time

The increase in the centrifugation time at 5000 rpm during the determination of the water absorption capacity of the starch of the cassava root *Manhiot esculenta* Crantz cv Bonoua 2 significantly decreased (p <0.05) the value of this physico-functional parameter. These values are between 149.28 ± 10.85% and 176.77 ± 2.80% for 10 min, 143.11 ± 4.05% and 164.27 ± 0.75% for 20 min, 155.06 ± 1.11% and 314.01 ± 1.73% for 30 min. At 10 min of centrifugation, the starch has a maximum value. The decrease in water absorption capacity is a function of particle size (Figure 5).

Influence of the starch concentration

The water absorption capacities obtained during the study of the influence of the concentration of the starch on the water absorption capacity of the starch are between 129.83 ± 0.73% at 158, 66 ± 6.22%, from 144.85 ± 4.76 to 162.46 ± 5.56%, from 163.74 ± 3.77 to 220.82 ± 7.42% and from 155.06 ± 2, 31 to 245.68 ± 6.88 respectively for starch concentrations of 5, 7.5, 10 and 20%. The increase in starch concentration results in a significant (p <0.05) increase in water absorption capacity. This increase depends on the grain size of the starch (Figure 6).

Solubility indices in water

Influence of the type of water

The water solubility indices of the four types of cassava root starch vary significantly at p <0.05 according to Duncan's test. The solubility indices in water of starches M0, M1, M2 and NT are respectively 18.86 ± 0.45%, 17.89 ± 3.39%, 16.33 ± 3.08% and 17.74 ± 4.08% in distilled water (Figure 7). The values obtained with tap water are 22.70 ± 0.79% for M0, 20.14 ± 0.79% for M1, 19.29 ± 1.14% for M2 and 18.21 ± 1.68% for NT. Tap water therefore increases the solubility index of cassava starch. This increase is a function of the grain size of the starch (Figure 7).

Influence of the incubation temperature

The variation in the starch incubation temperature during the determination of the water solubility index of Bonoua 2 starch made it possible to note that at temperatures of 60 and 65 ° C, the solubility indices in the water have reached their maximum. They vary from 30.88 ± 3.52% to 80.66 ± 5.39%. The solubility indices in water at temperatures below 65 ° C for all starches are higher than those obtained at the standard temperature (37 ° C) (Figure 8). This situation shows that the starch incubation temperature positively and significantly (p <0.05) influences the starch solubility in water and also depends on the particle size.

Influence of centrifugation time

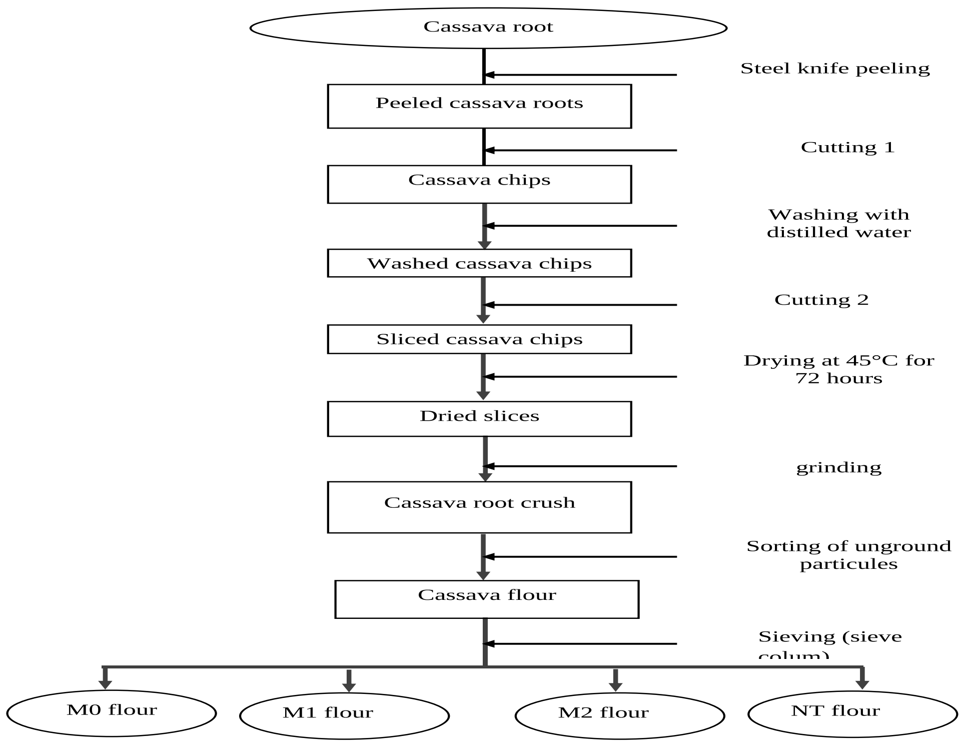
The increase in centrifugation time during the determination of the starch solubility indices of the cassava root *Manhiot esculenta* Crantz cv Bonoua 2 significantly increased (p <0.05) the value of this physico-functional parameter. At 30 min of centrifugation, the four starches M0, M1, M2 and NT showed maximum values. They are respectively 22.05 ± 1.11, 22.15 ± 1.26, 25.37 ± 1.45 and 20.34 ± 1.86%. The centrifugation time of the samples therefore influences the solubility of the starch in the cassava root and takes into account the particle size (Figure 9).

Influence of the starch concentration

The results obtained revealed that the solubility index decreased significantly (p <0.05) with increasing starch concentration.

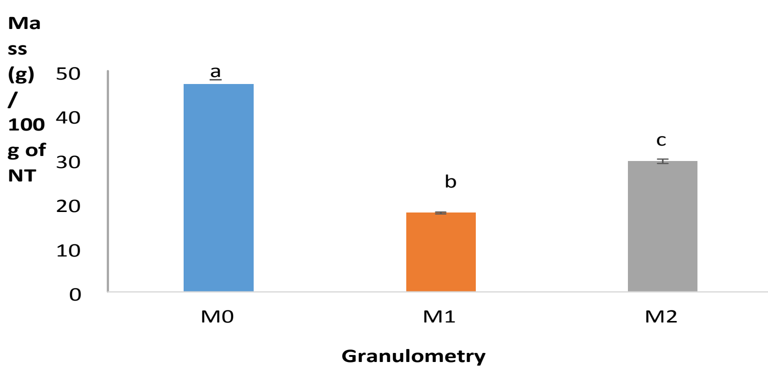
This decrease is also linked to the type of starch, that is to say to the grain size of the starch. The solubility index in water varies from 15.56 ± 2.91% to 17.97 ± 0.45% for the concentration of 5%, from 20.06 ± 3.08 to 43.59 ± 2, 62% for the 15% concentration and from 22.057 ± 0.818 to 57.573 ± 5.799 for the 20% concentration (Figure 10).

Fig.1 Production diagram of the different cassava root flours (*Manhiot esculenta* cv *Bonoua 2)*



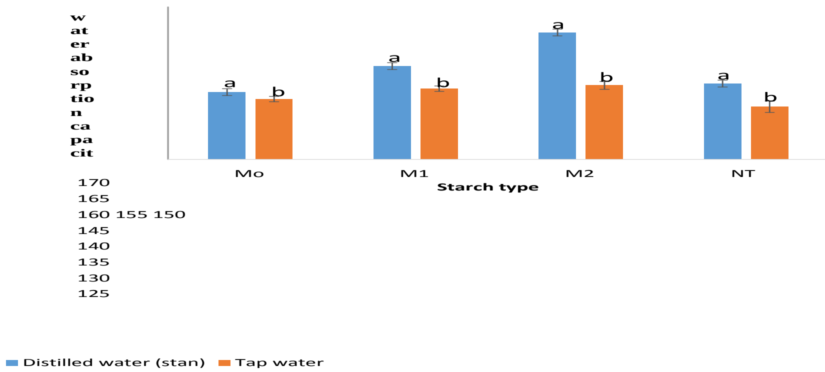
M0 (grain size <250 µm); M1 (250 µm <grain size <500 µm); M2 (500 µm <grain size <750 µm); NT (unsifted starch)

Fig.2 Starch masses obtained as a function of particle size from 100 g of total dry ground material from the cassava root *Manhiot esculenta* Crantz cv Bonoua 2



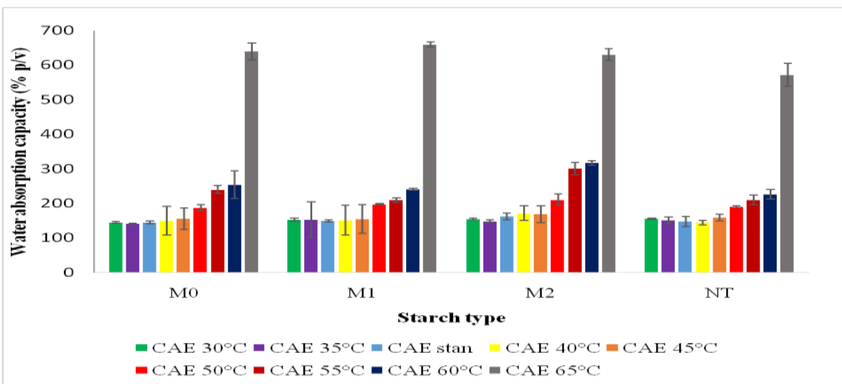
M0 (grain size <250 µm); M1 (250 µm <grain size <500 µm); M2 (500 µm <grain size <750 µm); NT (unsifted starch)

Fig.3 Influence of the type of water on the water absorption capacity of the starches of the cassava root *Manhiot esculenta* Crantz cv Bonoua 2



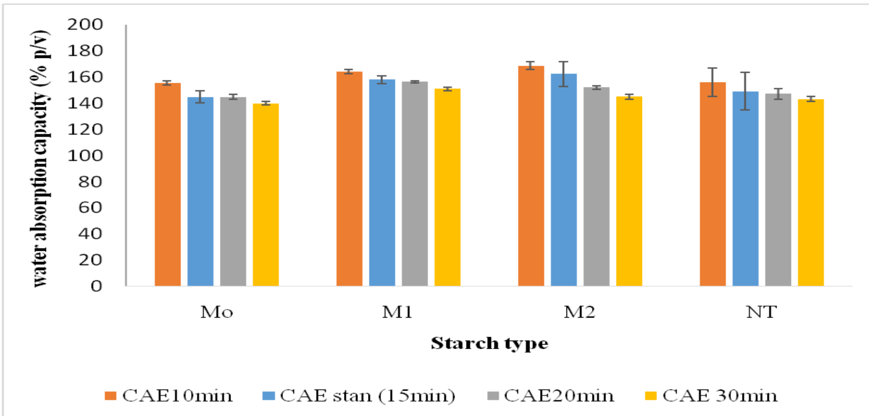
M0 (grain size <250 µm); M1 (250 µm <grain size <500 µm); M2 (500 µm <grain size <750 µm); NT (unsifted starch)

Fig.4 Influence of the incubation temperature on the water absorption capacity of the starches of the cassava root *Manhiot esculenta* Crantz cv Bonoua



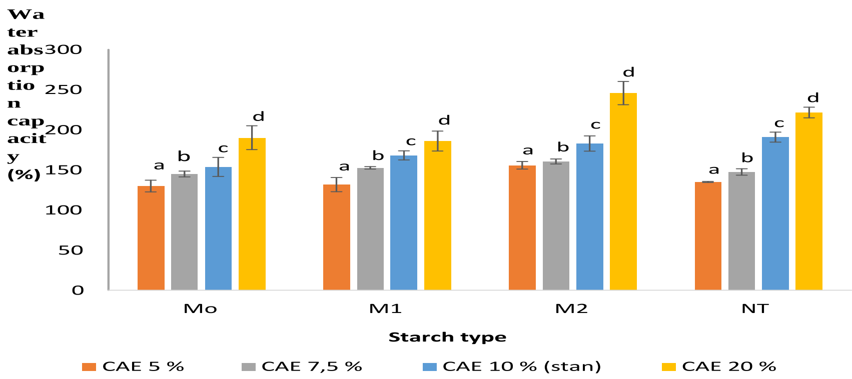
M0 (grain size <250 µm); M1 (250 µm <grain size <500 µm); M2 (500 µm <grain size <750 µm); NT (unsifted starch)

Fig.5 Influence of the centrifugation time on the water absorption capacity of the starches of the cassava root *Manhiot esculenta* Crantz cv Bonoua 2



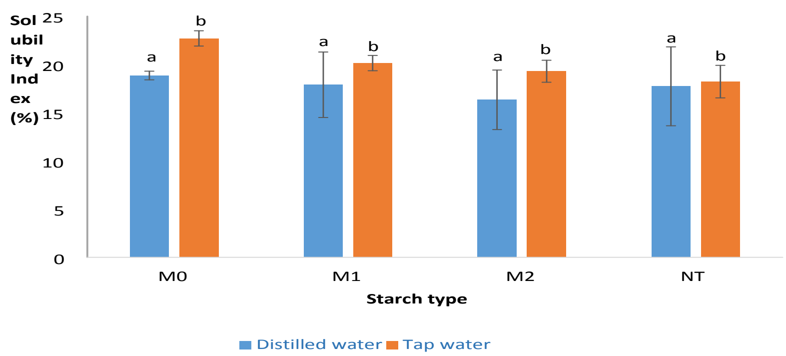
M0 (grain size <250 µm); M1 (250 µm <grain size <500 µm); M2 (500 µm <grain size <750 µm); NT (unsifted starch)

Fig.6 Influence of the concentration on the water absorption capacity of cassava root starches *Manhiot esculenta* Crantz cv Bonoua 2



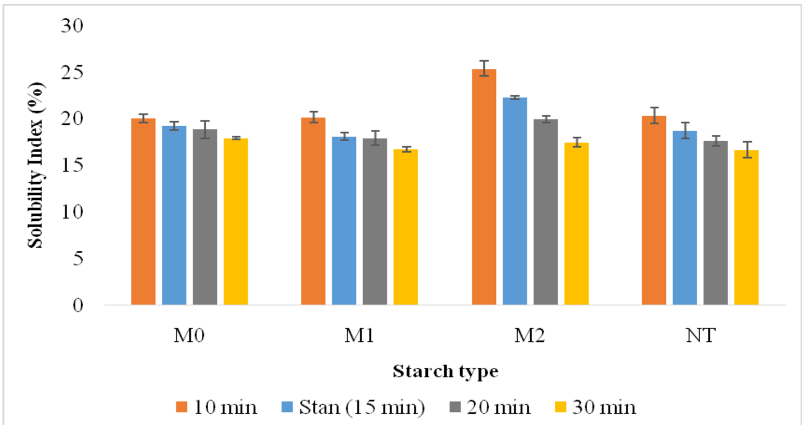
M0 (grain size <250 µm); M1 (250 µm <grain size <500 µm); M2 (500 µm <grain size <750 µm); NT (unsifted starch)

Fig.7 Influence of water type on the water solubility index of cassava root starches *Manhiot esculenta* Crantz cv Bonoua 2



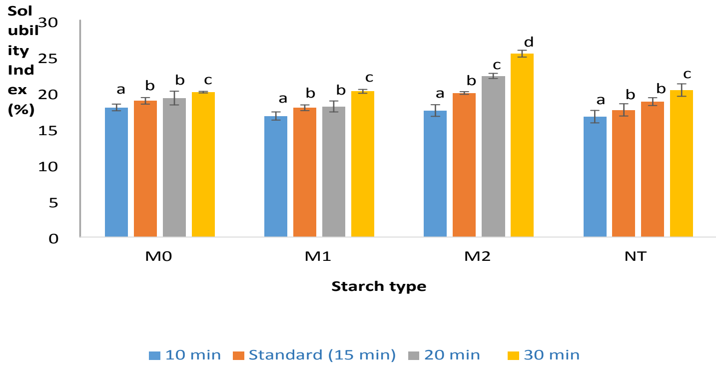
M0 (grain size <250 µm); M1 (250 µm <grain size <500 µm); M2 (500 µm <grain size <750 µm); NT (unsifted starch)

Fig.2 Influence of centrifugation time on the solubility index of cassava root *Manhiot esculenta Crantz cv Bonoua* 2



M0 (grain size <250 µm); M1 (250 µm <grain size <500 µm); M2 (500 µm <grain size <750 µm); NT (unsifted starch)

Fig.9 Influence of centrifugation time on the water solubility index of cassava root starches *Manhiot esculenta* Crantz cv Bonoua 2



M0 (grain size <250 µm); M1 (250 µm <grain size <500 µm); M2 (500 µm <grain size <750 µm); NT (unsifted starch)

Fig.10 Influence of the starch concentration on the water solubility index of cassava root starch *Manhiot esculenta* Crantz cv Bonoua 2

M0 (grain size <250 µm); M1 (250 µm <grain size <500 µm); M2 (500 µm <grain size <750 µm); NT (unsifted starch)

The particles whose sizes are less than 250 µm are the most represented in the total dry ground material of the cassava root *Manhiot esculenta* cv Bonoua 2. This result is different from that obtained by Abiodun *et al.,* (2013) who found that in the total crushed tuber of the yam Dioscoreadumetorum, the most represented particles are those of the sizes of 315 and 500 µm. These differences in results could be explained not only by the botanical origin but also by the grinding time, the type and the force of the grinder.

Water absorption capacity is a very important property of starches used in food preparations (Ikegwu *et al.,* 2009). The water absorption capacity varies significantly (p <0.05) depending on the particle size of the starch. This behavior would be due to the fact that the starches M0, M1, M2 and NT of different particle sizes could have different levels of hydrophilic groups. These can come either from carbohydrates or proteins. This observation has also been noted by some authors such as Savlak *et al.,* (2016) and Lucas-González *et al.,* (2017), who worked respectively on the effect of particle size distribution on some physical, chemical and functional properties of unripe banana starch and persimmon (Diospyros kaki Trumb.). In contrast, our results differ from those of Ahmed *et al.,* (2016) who worked on the effect of particle size distribution on the functional, thermal, rheological and gelling properties of Indian and Turkish lentil starches and found water absorption capacities of less than 100%. M1 and M2 starches have the highest water absorption capacities regardless of the solvent used. These are starches, the particle sizes of which vary between 250 µm and 750 µm. The water absorption capacity is even greater with M2 starch, the particle size of which is between 500 and 750 µm. This shows that fine starches absorb less water than those containing large particles. This behavior is contrary to that of Rao *et al.,* (2016) worked on the influence of milling methods and particle size on the hydration properties of sorghum starch and on the quality of sorghum cookies. For these authors, the water absorption capacity is higher with fine sorghum flour. The water absorption capacity of the cassava starch studied drops significantly ($p < 0.05$) depending on the type of water (distilled water and tap water) used as solvent.

This situation means that the type of water influences the availability of hydrophilic groups. Tap water, generally used in the food industry in food preparation, decreases the availability of these hydrophilic groups. This situation suggests that the water absorption capacities determined in the laboratory with distilled water do not reflect industrial reality. With distilled water, we would overestimate the water absorption capacities. The water absorption capacities obtained in this work are much higher than those of Ikegwu *et al.,* (2009) (59.75 - 68.02%), on the starches of 13 improved cassava varieties, but lower than those of the yam tuber (176.47 to 182.69%) reported by Amoo *et al.,* (2014) on starches from four varieties of yam. The high water absorption capacity of our starches could be attributed to the low amylose content of cassava starch. The increased water absorption capacity in food systems allows bakers to manipulate the functional properties of dough in bakery and pastry products (Ikegwu *et al.,* 2009). The studied cassava starches having a high CAE could be useful in the formulation of bakery, pastry, soups and sausage products. The increase in the incubation temperature during the determination of the water absorption capacity of the starch of the cassava root allowed to improve significantly ($p < 0.05$) this physico-functional parameter at temperatures above 50°C. According to Sanni *et al.,* (2006), this increase in water absorption capacity could be attributed to the loss of the crystal structure of starch polymers because a decrease in value indicates the compactness of the molecular structure. Indeed, an increase in the incubation temperature of the starch causes the starch grain to pass through three important physical stages, namely absorption, swelling and bursting. These physical changes cause the starch grains to lose their crystal structure. The evolution of the water absorption capacity as a function of the incubation temperature of the starch of the cassava root *Manhiot esculenta* cv Bonoua 2 is different from that obtained by Olawuni *et al.,* (2014). Indeed, these authors found that the incubation temperature of the starch and the protein isolate of cowpea seed (*Vigna unguiculata*) at 40° C gave a high water absorption capacity while at the temperature of 70 ° C, low water absorption capacity was obtained. The increase in centrifugation time significantly ($p < 0.05$) decreases the water absorption capacity of the starches when the centrifugation speed is 5000 rpm. This behavior is therefore linked to the particle size of the starch. Long centrifugation results in a decrease in the amount of water absorbed and weakly bound. It leaves those which are strongly held and which are stable. Indeed, Rey and Labuza (1981) have shown that the presence of water in foodstuffs and its quantity depend on the absorption capacity and the stability of water. The increase in the concentration of starch promotes a significant increase ($p < 0.05$) of the water absorption capacity. This increase is also a function of the grain size of the starch. The more the starch concentration increases, the more the starch's water absorption capacity increases. This increase is due to an increase in the number of particles in the reaction medium which would absorb more water. The reaction medium would contain more hydrophilic groups, i.e. starch and proteins.

The water solubility index reflects the extent of starch degradation (Mbofung *et al.,* 2006). It is an indicator of the water penetrating abilities in the starch granules. Tap water promotes an increase in the starch solubility index of the cassava root, *Manhiot esculenta* cv Bonoua 2. This increase is a function of the grain size of the starch. An increase in the water solubility index reflects an increase in denaturation of the starch grain, a major substance in the biochemical composition of cassava root. In fact, tap water could contain substances likely to promote the transformation of the crystalline starch grain into amorphous starch or would contain impurities. The solubility indices of cassava root starches are higher than those of taro tuber starches (about 10%), (Mbofung *et al.,* 2006). The incubation temperature influences the solubility index of the starch of the cassava root *Manhiot esculenta* cv Bonoua 2. This situation is more marked at temperatures of 60 and 65 ° C where the water solubility index is maximum regardless of the particle size. This increased solubility in water could be attributed to the phenomenon of gelatinization of the starch contained in the starches of the cassava root. Indeed, according to Slimane (2010), the behavior of starch granules varies with temperature. During the heating process of starch, the crystal structure of starch is disrupted due to the breakdown of hydrogen bonds. Water molecules bind with a hydrogen bond to the free hydroxyl groups of amylose and amylopectin, causing increased swelling of the granules and their solubility (Babu and Parimalavalli, 2012). Solubility therefore increases with increasing temperature due to the increased mobility of starch granules, which facilitated the dispersion of starch molecules in water at temperatures above 50 ° C (Valcárcel-Yamani *et al.,* 2013).The centrifugation time influences the solubility index of the starch of the cassava root, *Manhiot esculenta* cv Bonoua 2, whatever the granulometry. The longer the centrifugation time increases, the more the water solubility index decreases. A long centrifugation time allows some particles to settle, thus increasing the pellet mass. The solubility index of the starch of the cassava root *Manhiot esculenta* cv Bonoua 2 decreases with the concentration of starch, unlike the water absorption capacity. This decrease is also linked to the type of starch, that is to say to the grain size of the starch. The greater the quantity of starch granules in the water in the reaction medium, the less the particles resulting from the degradation of starch differ in the water. Water therefore becomes a limiting factor

In conclusion at the end of this study, we can retain on the one hand that the particles whose sizes are less than 250 µm are the most represented in the total dry ground of the cassava root and on the other hand that the extrinsic factors such as the type of solvent, the incubation temperature, the concentration of starch in the reaction medium and the centrifugation time influence the determination of the water absorption capacity and the water solubility index of the starchcassava root *Manhiot esculenta* cv Bonoua 2. The comparison of these physico-functional parameters with those of other starches must take these factors into account. Special arrangements must be made to specify the conditions under which the water absorption capacity and the water solubility index are obtained.

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