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Morphological Characteristics of Starch Granules from Yam Tuber Parts of "Florido" and "Bètè-Bètè" Cultivars (*Dioscorea alata*) During the Post-harvest Storage

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Abstract: It is paramount important to know that starches are extracted from tuber parts of two yam cultivars (*Dioscorea alata*) during the post-harvest storage for up to 6 months. The granules related to these starches were investigated for morphological properties during post-harvest storage. The results revealed that the shapes of the starch granules did not vary from one part to another, even if the cultivar is for the same storage time and during the post-harvest storage. Indeed, the tuber parts of "Bètè-bètè" cultivar are constituted of granules with round, oval and oblong shape. Besides, the shape of starch granules of "Florido" cultivar varied from round to ovotriangular. In general, the distribution of the starch granules was unimodal. The distribution of the granules size ranged from 4.63-50.96 µm in the proximal tuber parts during the post-crops storage. As for distal tuber parts, it ranged from 4.56-44.71 µm. Otherwise, the results also showed that the average diameters of the granules appear significant ($p \leq 0.05$) from one tuber part to another and during the post-crops storage. They all decreased during the storage. The proximal tuber parts had the highest size of the granules (Ø = 24.37-30.71 µm). Among the two studied cultivar, the parts of "Florido" cultivar presented the highest size of starch granules.

Key words: Yam, tuber part, granules, starch, morphology, postharvest storage

INTRODUCTION

Yams (*Dioscorea alata*) are grown widely in tropical and subtropical regions of the world. They are plants yielding tubers and contain starch between 70 and 80% of dry matter (Zhang and Oates, 1999). The most cultivated and consumed yams of *Dioscorea alata* species in the center of Cote d'Ivoire were "Bètè-Bètè" and "Florido" (Doumbia *et al*., 2006). Yams, the edible tubers of various species of the genus *Dioscorea*, are important staple foods and a potential source of ingredients for fabricated foods in many tropical countries because of their high starch content. The starches are the major storage polysaccharides in root and tuber crops (Chien-Chen *et al*., 2005). It was important to better know their characteristics and properties for their use. Besides, several works carried out on the whole yam tuber starches among others those of by Amani *et al*. (2004b) and Sahore *et al*. (2005), Chien-Chen *et al*. (2005) and Sahore and Amani (2007) who are worked on "variability in starch physicochemical and functional properties of yam (*Dioscorea* sp.) cultivated in Ivory Coast", "the properties of starches from some Ivory coast wild yam (*Dioscorea* sp.) species", "changes in morphological, thermal an pasting properties of yam (*Dioscorea alata*) starch during growth" and "Morphological characteristics and cristalline structure of granules of some wild yam species (*Dioscorea* sp.) from Côte d'Ivoire forest zone" respectively. However, little attention has given to the native starches of the yam tuber parts (proximal, median and distal) and during the post-harvest storage to determine their morphological characteristics, hence the importance of this study. The interest to know these properties could be registered inthis dynamics of research.

The purpose of the present study was to examine the effect of different part and the storage time on the starch granules shape and size of some edible yam tuber parts from Tiebissou (central part of Cote d'Ivoire) during the first six month post harvest storage. Our results of survey came to perfect the former work carried out on yam tuber starches.

MATERIALS AND METHODS

Raw material: The most cultivated and consumed cultivars of *Dioscorea alata* species in the center of Cote d'Ivoire that are "Bètè-Bètè" and "Florido" were selected for this study. Tubers about 44.07±4.46 cm were harvested in fields of "Tiébissou" department villages (center of Cote d'Ivoire). Then, they were kept for six months in a heap aired store in which the temperature and the relative humidity rate are respectively 26.56°C±3°C and 82%±5%.

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Starch isolation: Yam starches were extracted according to the procedure of Delpeuch *et al.* (1978) previously described by Amani *et al.* (2002). Every two (2) months of storage during six (6) months, four yam tuber of each cultivar was randomly picked. These tubers were cut into three pieces and giving three lots of yam constituted of the proximal parts (head of tuber), the median parts and the distal parts (tail of tuber). One Kilogram (1 kg) of each yam cultivar lot was weighed, washed and peeled. Immediately after peeling, the yam lots were cut out into small slices (4 x 4 cm) with knife made of rustproof steel and steeped in distilled water containing 0.1% (w/v) sodium metabisulphite. The slices were ground in a grinder (Moulinex, Lyon-France) and the paste recovered in 4% (w/v) sodium chloride solution to separate proteins from the starch. The slurry was sieved successively through 750 μm, 150 μm and 100 μm sieves. Then, the starches were alternatively decanted and washed at least four times with distilled water. The starch suspensions were dried at 45°C for 48 h with the ventilated drying oven Mettenter (MMM) Venticell (Brno-Czech republic). The dry products were ground, quantified and then stored for analyses.

Light microscopy: Light microscopy was employed to characterize native starches with respect to appearance, shape and size of granules (Schoch and Maywald, 1956).

The shape of the native starch granules was observed to photonic microscope (CETI, Kontich-antwerp-Belgium) that provided camera (Sony, Tokyo-Japan). It was connected to a computer and a JVC screen (Paris-France). The shape was defined by the coloration of starch granules with lugols (0.2 g iodine in 2% KI solution). The size of the native starch granules in suspension was measured on a microscopic scale with the help of the Kappa Software on computer connected to photonic microscope and the JVC screen (Paris-France).

Frequencies distribution of the average diameter of starch granules: The distributions of the average diameter of starch granules were given on a total of 500 granules (Rasper, 1971). They were carried out according to the rule of Sturge (Scherrer, 1984) and translated by the histograms.

Statistical analysis: The mean values and standard deviations of starch granule size were reported. Analysis Variance (ANOVA) was performed of this data analysis with the help of the software STATISTICA 7 (Statsoft Inc, Tulsa-USA Headquarters) and XLSTAT-Pro 7.5.2 (Addinsoft Sarl, Paris-France) The significantly difference was defined ($p \leq 0.05$). The rule of Sturge was carried out to determine the classes and associated amplitude.

RESULTS

Morphological properties: The morphological granular of the native starch granules of different tuber parts from "Bètè-bètè" and "Florido" cultivars different tuber parts during the post-harvest storage are presented in Fig. 1 and 2 respectively and the physical characteristics in Table 1. This study showed the same morphological variability from one part to another for each cultivar that did not vary during post crops storage for up to 6 months. The ANOVA revealed that the main effects and their interaction appeared significant at 0.05 level. There was also significant variation among the starch granule size from two cultivars and between the different tuber parts during the storage at 0.05 level. The shape of starch granules of different tuber part from "Bètè-bètè" cultivar appeared oval and sometime oblong, while the starch of different tuber part from "Florido" cultivar showed ovotriangular granules shape. So, the granules size of starch from "Bètè-bètè" was ranged from 22.09-24.37 μm, 20.90-23.00 μm and 18.50-22.51 μm for proximal, median and distal tuber parts respectively (Table 1). Furthermore, the granules size of "Florido" cultivar varied from 30.71-25.22 μm, 30.23-23.11 μm and 25.02-22.51 μm for proximal, median and distal parts respectively.

Frequency distributions: The granule size distributions of different yam starches were carried out by taking the size which was the average diameter between the lengths of the long axis and the short axis of the granule according to Rasper (1971). Indeed, the full granule size distributions of isolated starches from the different parts of "Bètè-bètè" and "Florido" cultivars are shown in Fig. 3-10. The intervals and the mode of starch granule size distribution are reported in Table 1. The distribution of native starch granules of studied yam tuber part was unimodal Fig. 3-10. In fact, the starch of yam tuber proximal part had the greatest interval of distribution and then the yam tuber distal part had the smallest interval of distribution. Besides, the starches of "Bètè-bètè" cultivar presented the smallest interval of distribution. Concerning the mode, the starches of yam tuber proximal part had the largest mode and those of the yam tuber distal part had the smallest mode during the post harvest storage.

Otherwise, to facilitate the comparison of frequency distribution of starch granules during the post harvest storage, we used the box plots Fig. 11. It provides an excellent visual summary of many important aspect of a distribution and summarizes the five following statistical measures: minimum, maximum, lower quartile or first quartile, second quartile or median and upper quartile or third quartile. The first quartile representing the lower hinge of the rectangular box was the smallest average diameter as 25% of the average diameter of starch granules are lower to its. The third quartile defining the

Table 1: Physical characteristics of starch granules of some yam tubers different part during postharvest storage

		Storage time							
		Month 0				Month 2			
Cultivars	Tuber parts	Granules shape	Interval size distribution (µm)	Mode (µm)	Average diameter (µm)	Granules shape	Interval size distribution (µm)	Mode (µm)	Average diameter (µm)
Bètè-bètè	PP	Oval Oblong	5.40-40.20	24.54	24.37±5.55	Oval Oblong	6.15-41.61	25.68	23.62±5.18
	MP	Idem	7.25-38.40	24.41	23.00±5.77	Idem	5.07-35.68	21.90	22.68±4.86
	DP	Idem	6.35-37.25	23.35	22.51±5.94	Idem	4.93-32.85	20.29	19.96±5.43
Florido	PP	Ovotriangular Oblong	11.98-50.96	33.43	30.71±7.06	Ovotriangular Oblong	8.01-47.29	33.56	30.65±7.11
	MP	Idem	6.94-51.00	26.79	30.23±7.03	Idem	8.35-49.50	31.13	28.96±6.82
	DP	Idem	5.57-43.86	26.64	25.02±6.48	Idem	6.41-44.71	23.65	24.49±5.99
		Month 4				Month 6			
Cultivars	Tuber parts	Granules shape	Interval size distribution (µm)	Mode (µm)	Average diameter (µm)	Granules shape	Interval size distribution (µm)	Mode (µm)	Average diameter (µm)
Bètè-bètè	PP	Ovale Oblong	6.69-37.77	23.80	22.74±5.75	Ovale Oblong	4.63-37.72	22.84	22.09±6.46
	MP	Idem	7.45-39.26	21.76	21.10±7.05	Idem	5.70-39.90	21.09	20.93±5.63
	DP	Idem	6.64-37.33	20.46	19.73±5.46	Idem	4.56-38.36	19.77	18.50±6.20
Florido	PP	Ovotriangular Oblong	8.35-48.01	26.22	29.26±6.08	Ovotriangular Oblong	5.19-44.14	22.74	25.22±6.75
	MP	Idem	6.40-47.29	24.81	27.48±6.75	Idem	7.07-38.81	25.06	23.11±6.17
	PD	Idem	6.52-37.32	23.46	23.35±5.22	Idem	6.35-37.25	23.35	22.51±5.94

PP: Proximal Part, MP: Median Part; DP: Distal Part; 0, 2, 4 and 6: Storage time

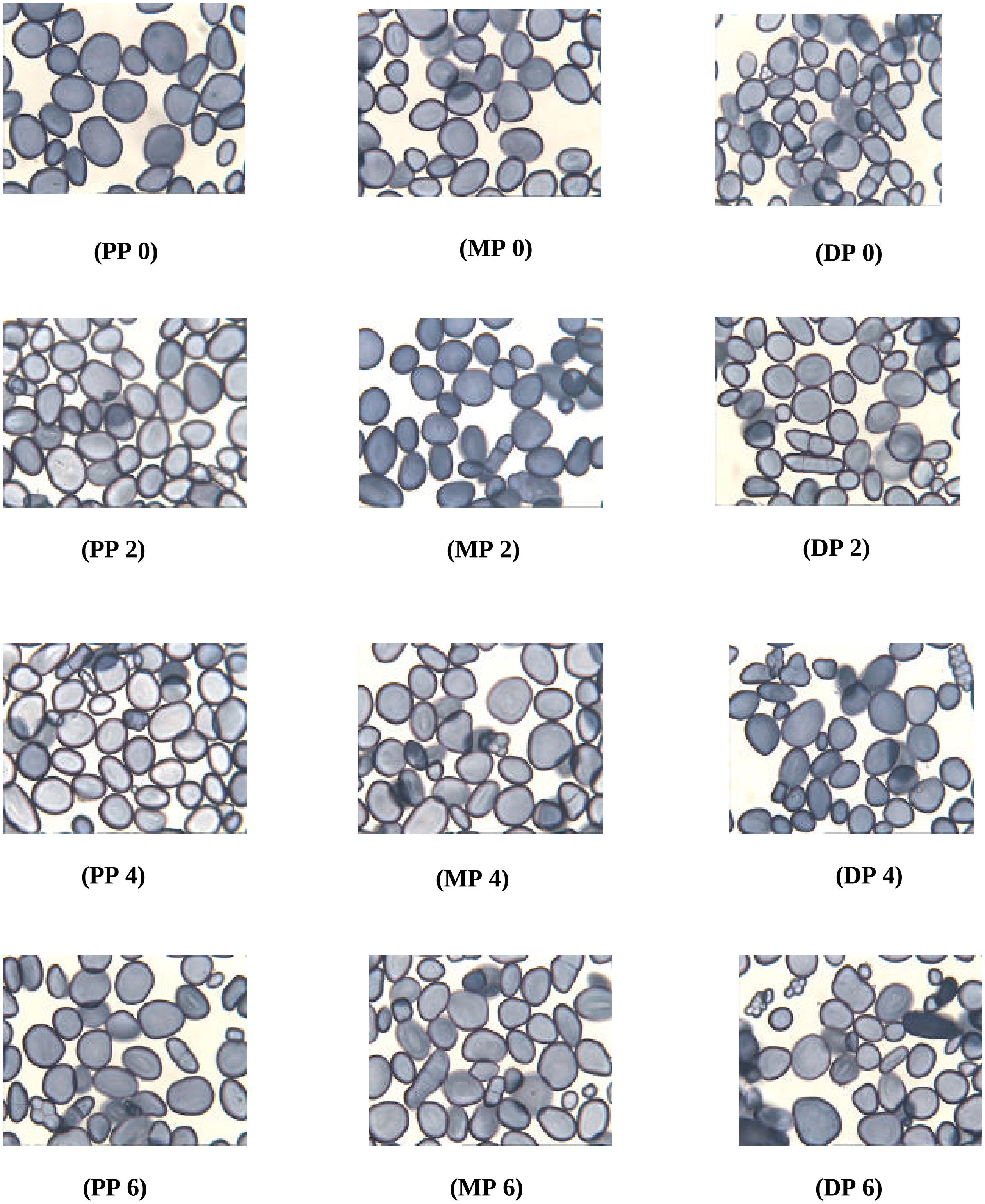

Fig. 1: Light microscopy of the native starch granules of "Bètè-bètè" cultivar tuber part from month 0 to month 6 (x400). PP: Proximal Part; MP: Median Part; DP: Distal Part; 0, 2, 4 and 6: storage time

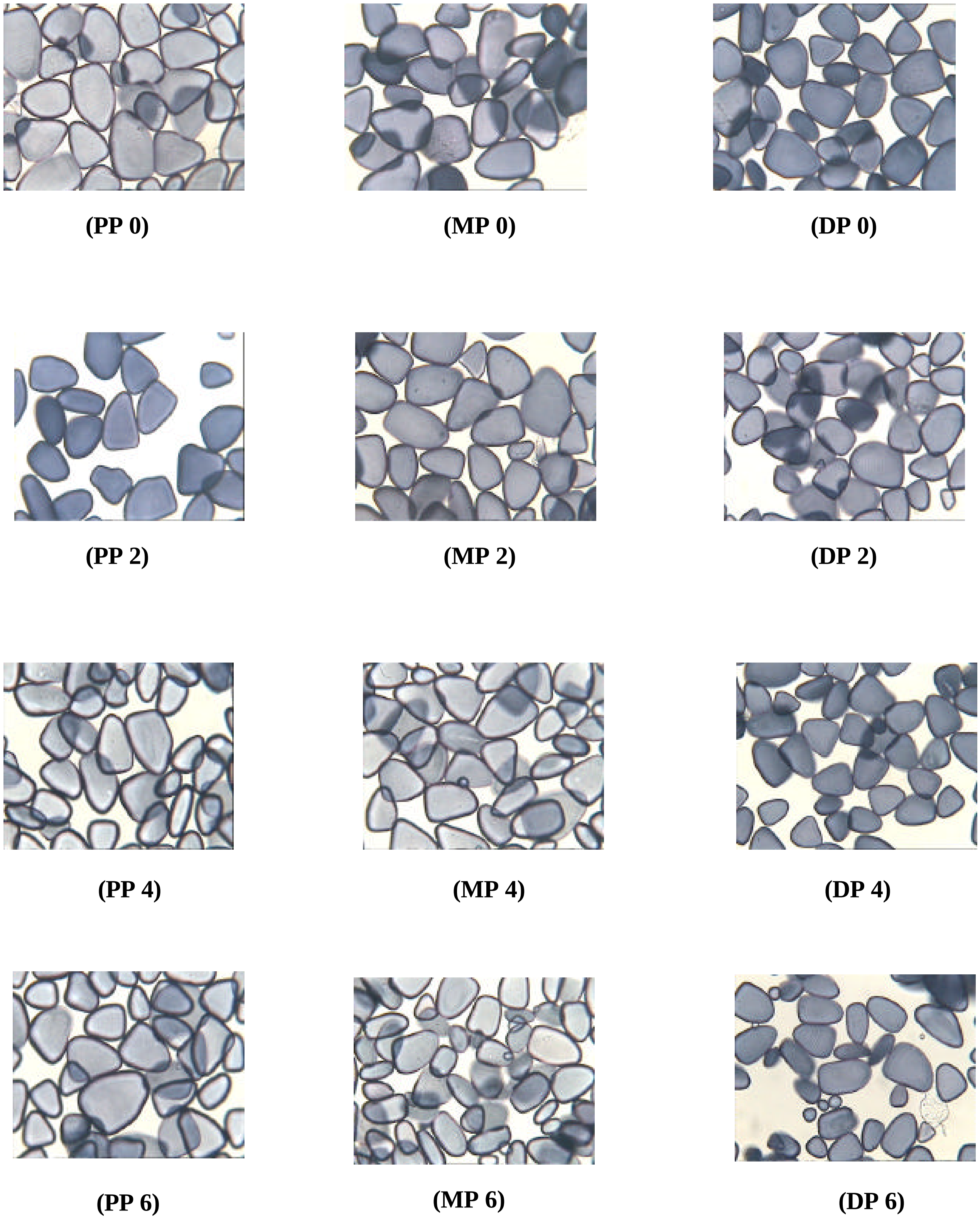

Fig. 2: Light microscopy of the native starch granules of "Florido" cultivar tuber part from month 0 to month 6 (x400). PP: Proximal Part; MP: Median Part; DP: Distal Part; 0, 2, 4 and 6: storage

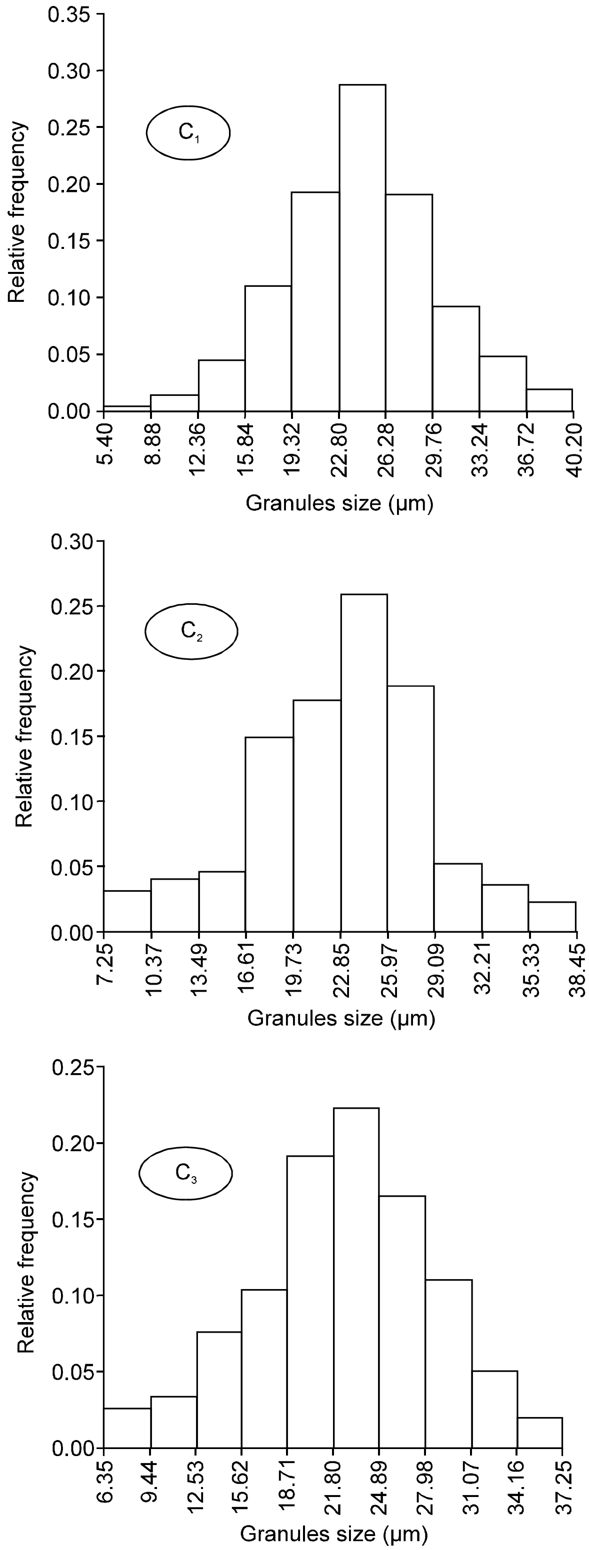

Fig. 3: Granule size distributions of native starch of proximal (C_1), median (C_2) and distal (C_3) yam tuber parts from "Bètè-bètè" cultivar at the month 0

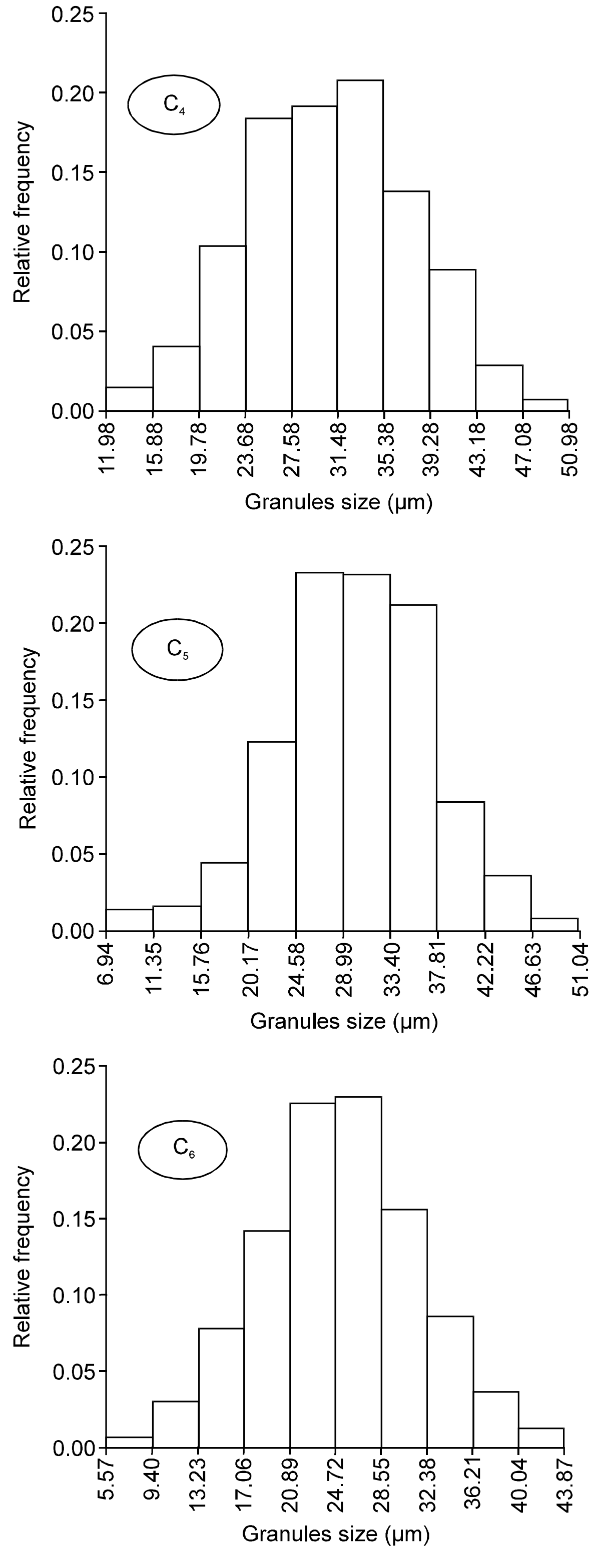

Fig. 4: Granule size distributions of native starch of proximal (C_4), median (C_5) and distal (C_6) yam tuber parts from "Florido" cultivar at the month 0

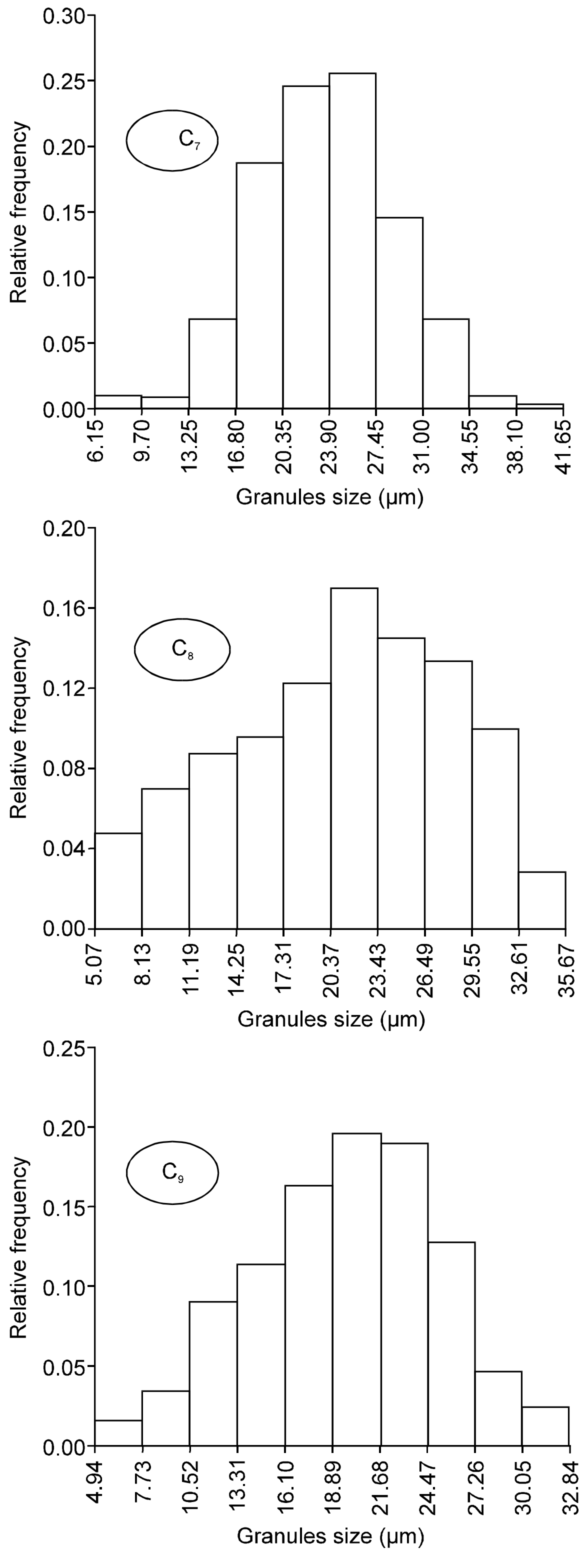

Fig. 5: Granule size distributions on of native starch of proximal (C_7), median (C_8) and distal (C_9) yam tuber parts from "Bètè-bètè" cultivar at the month 2

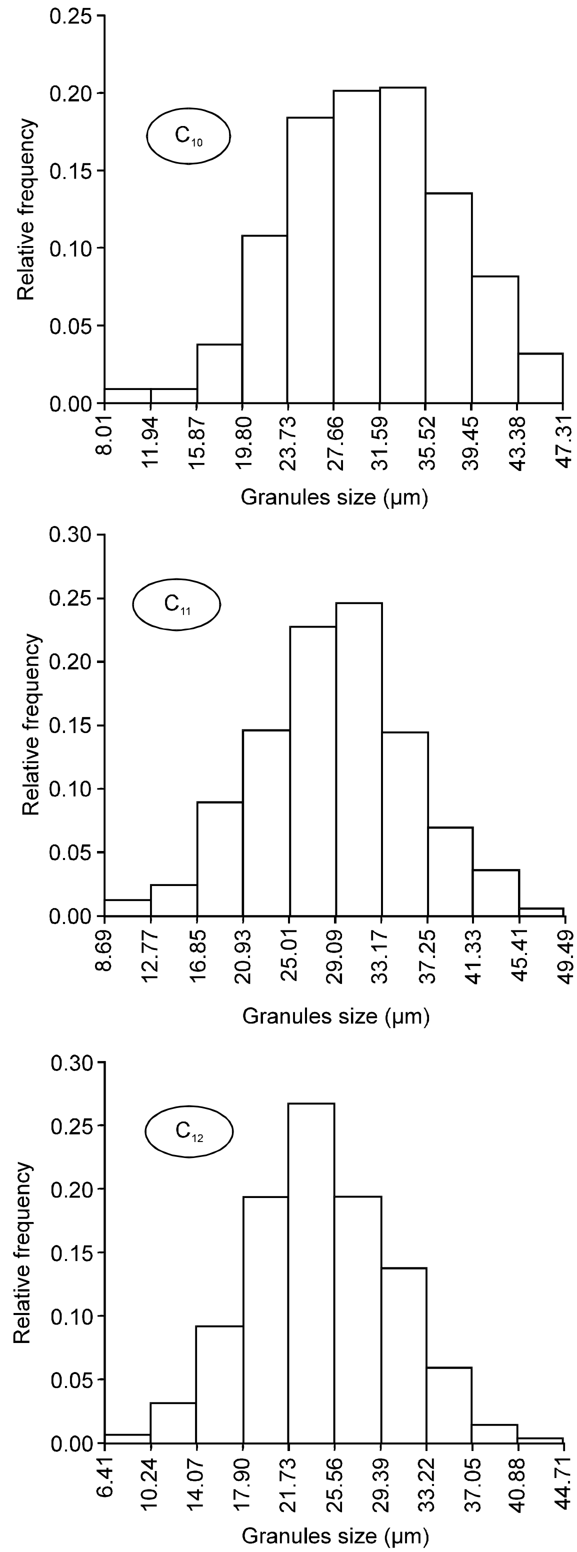

Fig. 6: Granule size distributions of native starch of proximal (C_{10}), median (C_{11}) and distal (C_{12}) yam tuber parts from "Florido" cultivar at the month 2

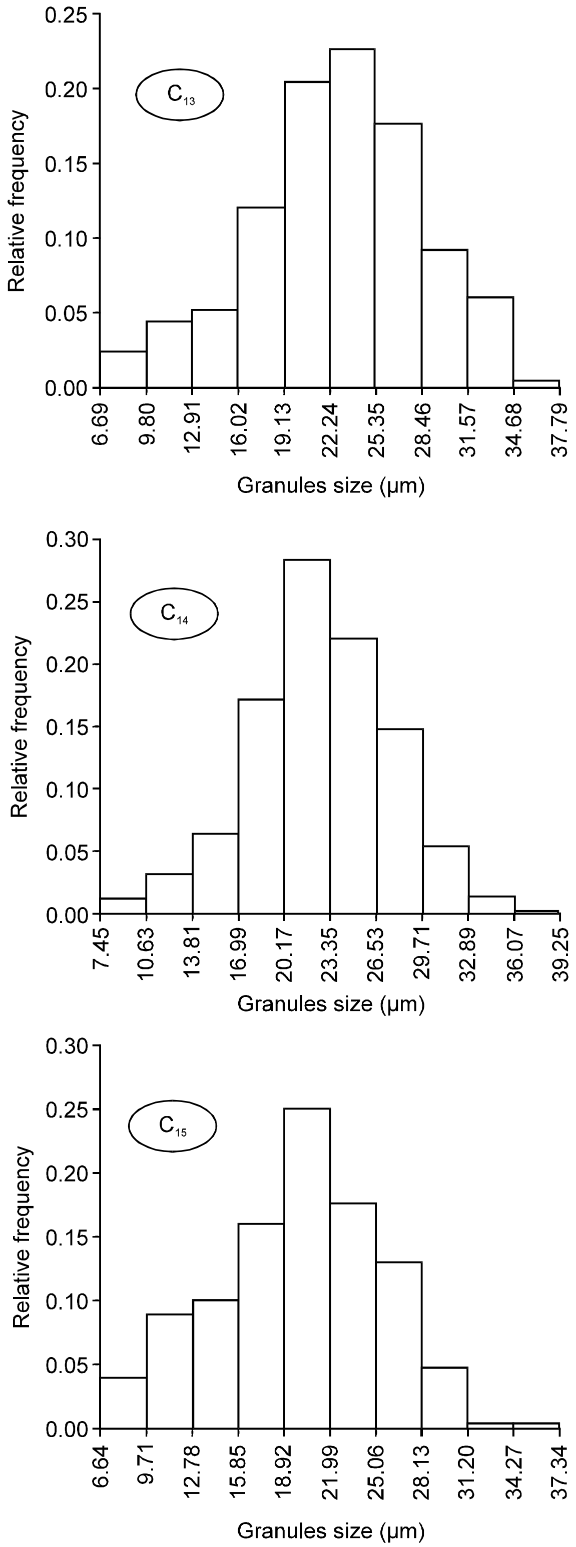

Fig. 7: Granule size distributions of native starch of proximal (C_{13}), median (C_{14}) and distal (C_{15}) yam tuber parts from "Bètè-bètè" cultivar at the month 4

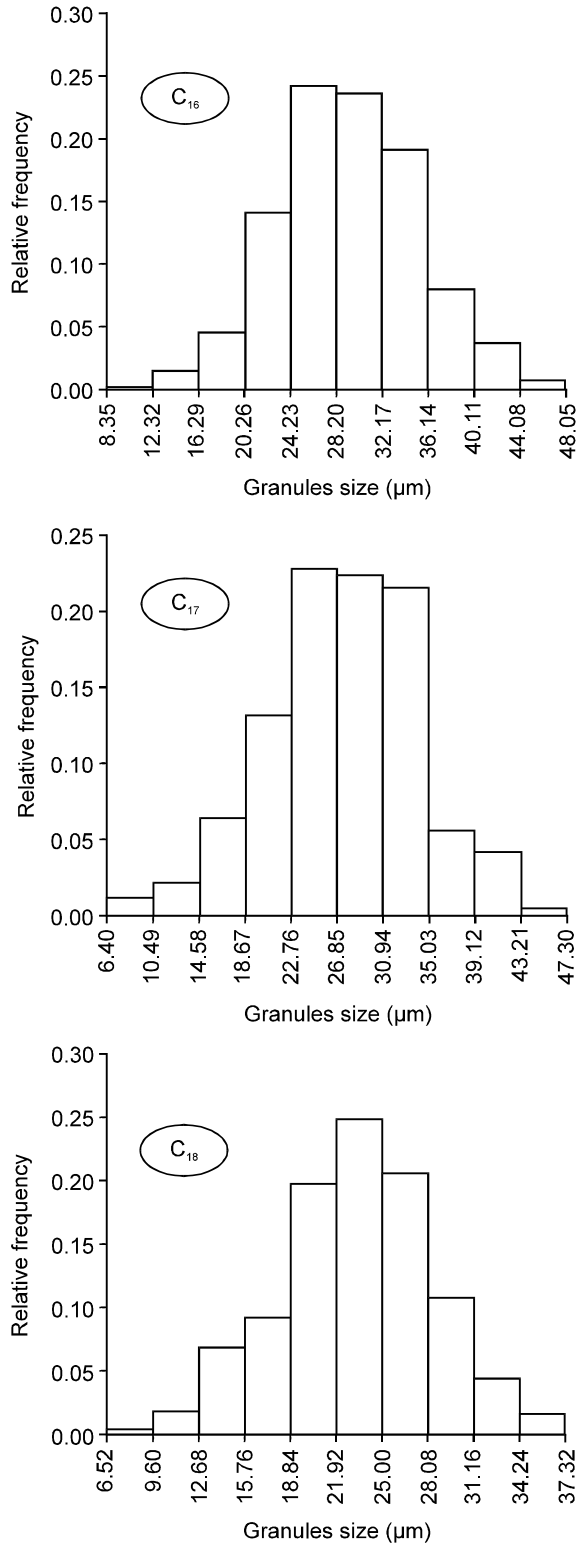

Fig. 8: Granule size distributions of native starch of proximal (C_{16}), median (C_{17}) and distal (C_{18}) yam tuber parts from "Florido" cultivar at the month 4

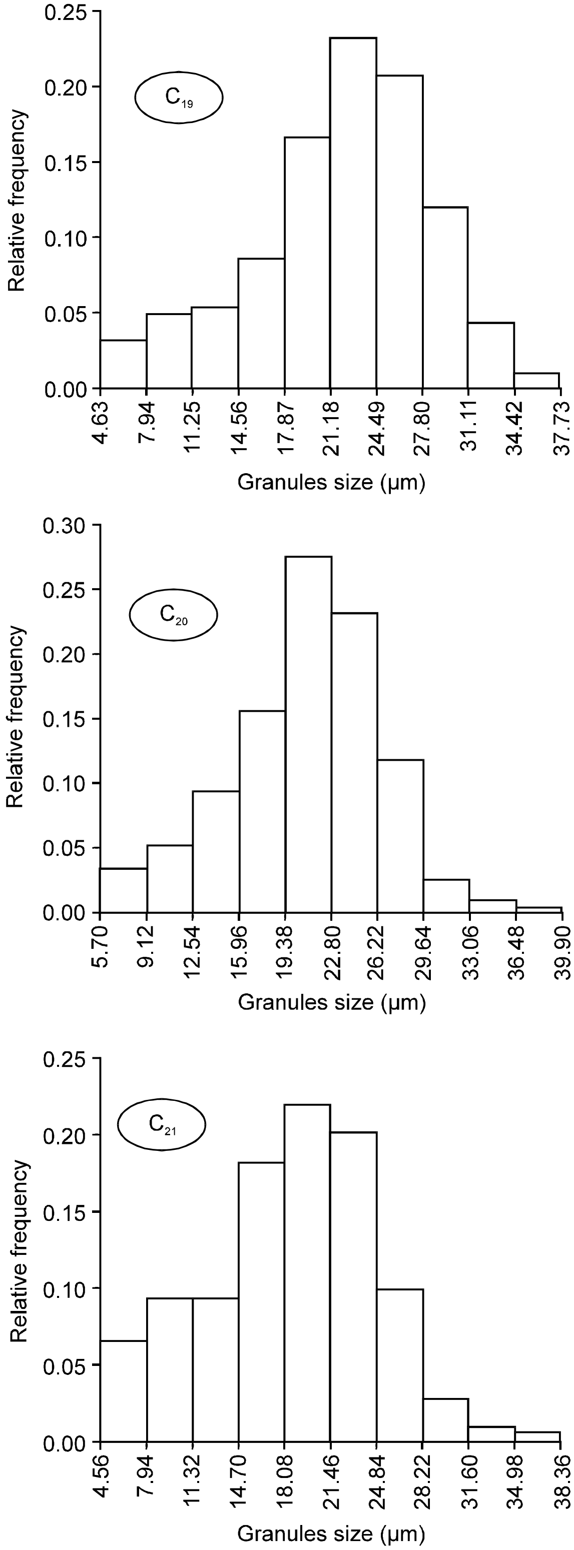

Fig. 9: Granule size distributions of native starch of proximal (C_{19}), median (C_{20}) and distal (C_{21}) yam tuber parts from "Bètè-bètè" cultivar at the month 6

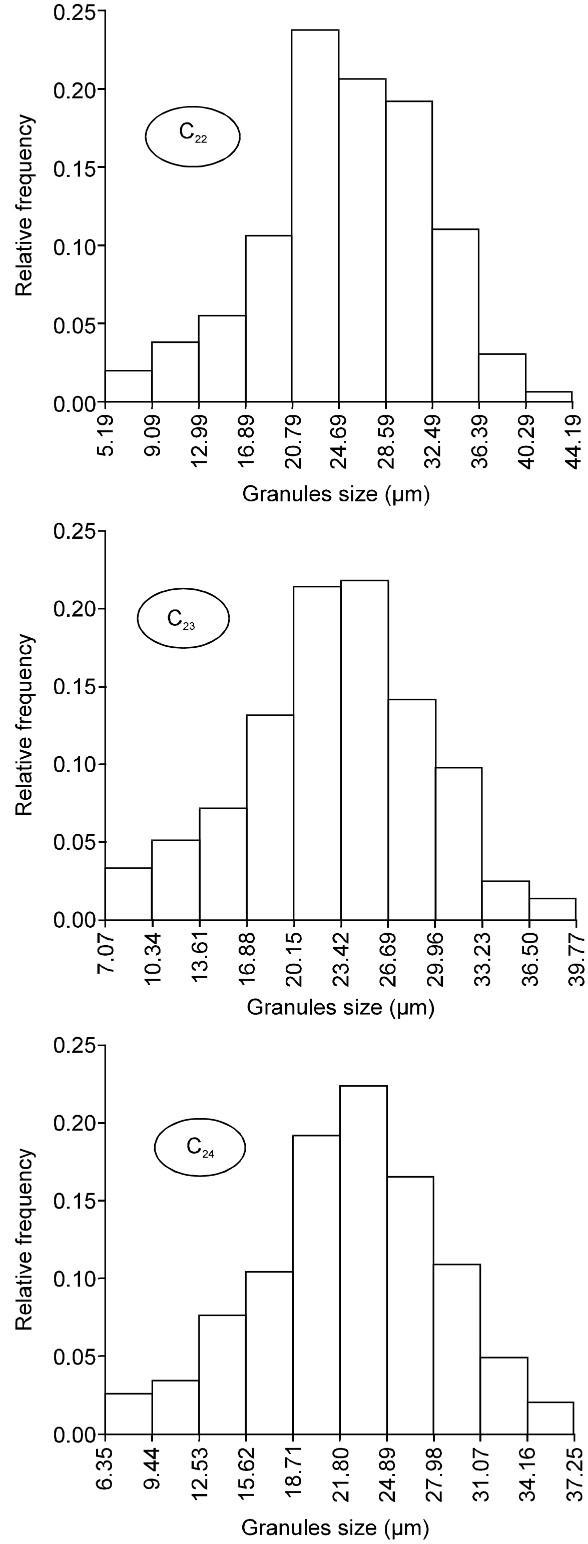

Fig. 10: Granule size distributions of native starch of proximal (C_{22}), median (C_{23}) and distal (C_{24}) yam tuber parts from "Florido" cultivar at the month 6

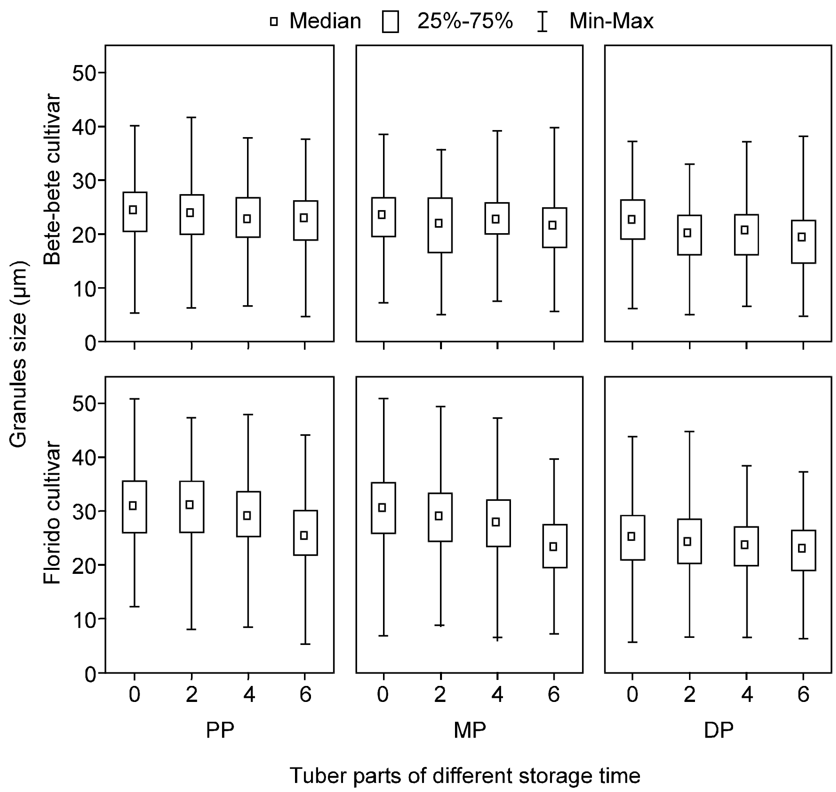

Fig. 11: Evolution of native starch granule diameter of different parts of "Florido" and "Bètè-bètè" cultivars during the postharvest storage

upper hinge of the rectangular box was the smallest average diameter as 75% of the average diameter of starch granules are lower to its. As the median, it is translated by the small square in the center of the rectangular box. The other two values always shown are the maximum and value of the data set. The third quartile that was more representative decreased during the post harvest storage whatever the yam tuber parts are. The highest values observed were those from the beginning month (month 0) for all tuber parts and the smallest values were those from the end month (month 6). The highest values of third quartile were showed in the proximal parts of the different cultivars and the smallest values in the distal part.

DISCUSSION

The study of the starch granule shape of two yam cultivar (*Dioscorea alata*) was carried out by several authors such as Delpeuch *et al.* (1978); Duprat *et al.* (1980); Treche (1989) and Amani *et al.* (2002). However, the morphology of the different yam tubers and during the storage was little known. The starch granule shapes observed in the proximal, median and distal parts were similar at the same storage time and during the storage. They agreed with those recorded by Delpeuch *et al.* (1978); Gallant *et al.* (1982) and Treche (1989) who indicated the ovotriangular, oblong and oval shapes in the whole tubers of *Dioscorea alata*. Indeed, the morphological characters of the native starch granule of the yam tubers could be attributed to the several factors of genetic nature (Degras, 1986). Contrary to the shape, the average diameter size of the starch granules varied significantly ($p \leq 0.05$) from one tuber part to another, with the highest values in the proximal parts and the lowest values in the distal parts whatever the variety was. The ranged values to the average diameter size of the different yam parts were near to those given by Gallant *et al.* (1982) who reported the average diameters of starch granules ranging from 20-140 µm for *Dioscorea alata*. However, our results were all slightly high than the reports of Vizcarrondo *et al.* (2004) and which indicated the average diameter size of starch granules varying from 21.83-35.00 µm for *Dioscorea bulbifera*. Compared to other root and tuber starches, the obtained results were also higher than those reported by Amani *et al.* (2004a) who found the average diameter size of starch granules ranging from 6.43-38.55 µm for *Zingiber officinale roscoe*. The heterogeneity of the starch granule size in the yam tuber with largest average diameter in the proximal parts may be due to the age of the different parts. Indeed, the formerly formed proximal parts would possess more aged and evolved tissues of those which were the result of the presence of more than high size and then the distal parts would present slight aged and evolved tissues. That would be explained by the presence of more small starch granule size in the distal part (Degras, 1986). The analysis of variance revealed significant differences ($p \leq 0.05$) during the storage between the average diameters of the starch granule at the month 0 and the month 6. The differences of the average sizes recorded from the month 2 to the month 4 were not significant at 0.05 level. The size of the starch granules was a parameter that would be determinative in the substantial interpretation of the starch properties (Deang and Del Rosario, 1999). Otherwise, the box plot generally permitted to confirm the symmetrical unimodality of the frequency distributions of the average diameter size of different tuber parts starch from the month 0 to the month 6, through the centered medians. It would translate that the distribution function of the starch granules of proximal, median and distal yam tuber parts, follows a normal law. These results are similar to those reported by Treche (1989) and Rasper (1971) who indicated the unimodality of yam tuber starch granule distribution. The box plot diagrams revealed that the starch granule size of different yam tuber parts decreased during the storage. It was translated by the variation of the third quartile, more representative, during the storage. The third quartile was higher in proximal part than other parts (median, distal) whatever the cultivar and storage time were, whereas it was smallest in tuber distal part. Indeed, 75% of the starch granules from "Florido" and "Bètè-bètè" cultivars proximal parts were lower or equal to 35.68 µm and 27.62 µm respectively at the beginning of the month (month 0) and then lower or equal to 30.12 µm and 26.51 µm respectively at the end month (month 6). This study revealed the existence of more and more small sized granules during the storage and this would be sustained by the amylasic hydrolysis increasing recorded by Diopoh and Kamenan (1981) during the post harvest storage. These results were in agreement with those of Barham and Wagoner (1946) mentioned by Treche (1989) on the starches of the sweet potato stocked in 30°C, with a relative humidity of 90% which were observed by the significant reduction of the granules size during the conservation.

Conclusion: The study of the physical aspect of starch granules showed that the starch granule of different yam tuber parts of the *Dioscorea alata* did not only present a morphological variability but the differences in distribution. The observed shapes in the tuber different parts were similar. The proximal part of the yam tuber had the highest size of starch granules and the smallest one in distal part, whatever the variety was. They all varied during the storage. The storage influences the starches granule sizes. Indeed, the factors that are cultivar, storage time and the tuber different part considerably influence the starch granules. It would be important to depend on these parameters to use the starch whatever the employment land is.

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