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Effect of planting distances on yield and quality of cassava cultivars and production of pasta from mixture of cassava flour and soft wheat flour

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THE PAPER targeted to study how planting distances affect quality, yield, and growth of cassava cultivars through 2022/23 and 2023/24 seasons. The data showed that the interaction between varieties and distances, the American cultivar increased the number of stem branches, weight, yield, diameter, dry matter, and starch percentage of tuber roots at a distance of 100 cm. While, the Brazilian cultivar enhanced height of the plants, the quantity of leaves, and the main stems at distance of 100 cm. However, the cultivar for Indonesia, The length of the tuber roots increased and the percention of fiber and hydrocyanic acid in cassava plants reached its maximum value with distance of 75 cm. Another goal of this study is to manufacturing pasta by mixing to three varieties of cassava flour is mixed with semolina at three different levels (10, 20, and 30%) to make pasta that has a better nutritional value and good sensory qualities. According to the results, pasta's Hunter color parameters (L*, a*, and b*) darkened when the amount of cassava flour added increased. The obtained sensory data, however, supported this conclusion. Pasta prepared with 10–30% cassava flour had higher weight, volume, and cooking loss than the control sample (pasta made entirely of semolina), according to the pasta's cooking quality. Additionally, pasta sensory evaluation revealed that all samples were acceptable; nevertheless, when compared to the control sample, the tenderness and stickiness of pasta fortified with 20% and 30% cassava flour do not differ significantly.

Keywords: Cassava, planting distance, cultivars, flour, pasta.

Introduction

Cassava considered non-traditional tuber roots vegetable plant. It is regarded as an annual agriculture crop even though it is a perennial crop. It is widely cultivated in areas that are tropical (Scott *et al*., 2000). The tuber roots of cassava, also known as tapioca (*Manihot esculenta* Crantz), are rich in starch and are grown for direct human consumption, animal feed, and industrial applications such as bread, biscuits, and pasta. Also, vegetative growth (leaves) is consumed as a vegetable for human and animal feed, which contain height concentricity of protein. It mattress the fourth feeding plants in developed nations because it is a major exporter of cheaper carbohydrates, calories, and maximum starch content in comparison to many others (Hassan, 2008). The distance between plants is considered to be the most important factor influencing plant development and yield. The planting distance shows great variation from one place to another depending on the cultured plant, land conditions whether clay or sandy, plant condition single or planted with other crops and the type of fertilization used (Balagopal *et al*., 1987).

Therefore, using the appropriate distance for growing cassava plants is considered an important factor in increasing the productivity of cassava yield. Ibrahim *et al*. (2004) and Hassan (2008), stated that when using space between same rows of cassava pants planting (150, 100 and 50 cm) the longest plant spacing (150 cm) gave the lowest value yield compared with short space (100 and 50 cm). Density between plants affects the crop and its quality (Samuel, *et al*., 2004 and Bussan, *et al*., 2007). The appropriate distance between plants increases yield because green leaves cover the ground first and are good at absorbing sunlight, which leads to the plant performing its function to the fullest extent. Little lateral branches also grow well and begin early yield producing (Beukema and Van Der Zaag, 1990). The optimal planting density varied according to cultivars and climatic conditions, according to Güllüoglu and Arıoglu (2009). In Egypt, there are three cultivates available

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in Agricultural Research Center (ARC), Horticulture Research Institute (HRI), Giza, Egypt in order to conduct experiments on them and definition the suitable distance for each cultivate.

As cassava is the fourth most important energy source in the diet of people in most tropical regions of the world, it is a good source of carbohydrates in the form of starch (Wheatley *et al*., 2003). Additionally, cassava's drought tolerance allows it to retain its nutritional content for extended periods of time without water, thus, showing the possibility for future food security in developing countries (Montagnac *et al*., 2009). The composition of cassava root is approximately 35 percent starch, 1.8 percent fiber, 1.3 percent ash, 1.2 percent protein, 0.3 percent fat, and 65 percent water. (Iwe *et al*., 2017). Fresh cassava roots are processed into flour, because of their short shelf life (Lu *et al*., 2020). The cost of producing cassava flour is considered to be lower than that of other flours made from corn and wheat (Aristizábal *et al*., 2017).

Pasta products, as essential foods, are expanding to meet the demands of contemporary living. They are well-liked due to their extended shelf life, inexpensive cost, and convenience of cooking, in addition to their sensory qualities, which consumers find acceptable. Carbohydrates compose 74–77% of pasta (Kadam and Prabhasankar, 2010). Noodles free gluten have a long shelf life and are transportable from their processing place. Despite these benefits, the production of maize noodles still requires ongoing quality improvement, and technological problem solving (Yalcin and Basman, 2008). In this regard, Scarton and Clerici (2022) stated that maize pasta is less attractive to consumers, more brittle, and prone to losing material after cooking, much like all gluten-free pasta. The absence of gluten causes all of these problems because it could produce a continuous matrix associated with the starch grains. Typically, wheat pasta (WP) is made with water and semolina then dried to preserve it. Customers like this product mostly because it's quick and simple to prepare. WP is also a common element in many dishes, high in energy, low in fat and sodium, and cholesterol-free. Although traditional pasta has a high carbohydrate content and only trace levels of dietary fiber, vitamins, and minerals, it can be enhanced with various raw ingredients to increase its nutritional and health benefits (Ghandehary Yazdi *et al*., 2020).

Cassava is an inexpensive source of starch and flour. Over 500 million people around the world depend largely on starchy cassava roots as a source of calories, making it the third most important food crop in the tropics after rice and corn (FAO, 1990). Nutritionally, cassava contains 62% water, 35% carbohydrate, 1% protein, 0.3% fat and 1% minerals (Westby, 1994). Since cassava is a cheap and healthy source of calories, it may be a decent alternative to wheat. This has drawn more attention in recent years, especially in developing nations where a large proportion of the population is low- to middle-income. Since cassava roots are perishable, they are processed into a cultivar of goods to enhance value and preserve them. These products differ according to the people's culture. Amongst the products are flour, tapioca, starch, garri, and lafun (Nwafor *et al*., 2015). Utilizing composite flour, which is made up of both wheat and non-wheat flour (such as cassava), has recently gained significant traction in developing nations like Nigeria. It represents one way of cutting down on the large amounts of wheat currently imported into the country for the production of flour-based products.

Additionally, diversity is required due to the prevalence of a well-known form of dietary intolerance (celiac disease) that is exclusively linked to foods that contain gluten, particularly wheat. Consequently, the need to get meals that are productive and economically feasible alternatives justifies studies that analyze foods that have the ability to totally or partially replace conventional foods (Menegassi and Leonel, 2005). Using substitute flours in pasta recipes may result in intriguing quality attributes and changes to the nutritional value of the different recipes (Inglett *et al*., 2005). Pasta is recognized to produce the highest-quality, because durum wheat contains a significant amount of protein and gluten. Since cassava flour doesn't contain gluten, it helps pasta dry and make dough that is more cohesive and plastic during extrusion (Antognelli, 1980); However, when combined with wheat flour, it appears to have potential (Baah *et al*., 2005).

Thus, the goal of this paper was to study how planting distances affect growth and production of cassava cultivars. Additionally, the study evaluated and compared pasta with pasta made from semolina based on a number of pasta quality parameters, including chemical composition, rheological qualities, color (L, a, b), cooking quality (weight increase, volume increase, cooking loss), sensory attributes, and texture profile.

Materials and Methods

1-Field experiment

The study's domain was located in recently reclaimed region during the two consecutive seasons of 2022–2023 and 2023–2024 at the National Research Center's experimental station in the Nubaria Region of the Behira Governorate in northern Egypt. The objective of this experiment was to investigate how planting distances affected the growth, quality, and yield of cassava cultivars. The second half of April was set aside for the planting of cassava in the 2022–2023 and 2023–2024 seasons. Every plot had a 10 m^2 size; one row, one meter of breadth, and ten meters of length. The field experiment included 6 treatments which were the combinations of 2 different factors, 3 different cultivars and 2 plant distances.

1. Cassava varieties supplied at Horticulture Research Institute, A.R.C., Giza, Egypt. Their names are Indonesian, Brazil and American.
2. Within each row, two plant distances of 75 and 100 cm were used. There were 13 and 10 plants in each plot, respectively.

Similar-thickness cassava stalks, measuring roughly 2.5 to 3.0 cm in diameter, were cut into 25 to 30 cm long stalk cuttings. These cuttings were then planted vertically, with two-thirds of them burred into the soil and the other third remaining above ground. They were then directly irrigated after planting. The drip irrigation system was used, with 25 cm spacing between nozzles for irrigation. Plant distances worked as the subplot and cultivars as the main plot in this split plot experiment. During two growth seasons, the main and subplot were displayed in randomized complete blocks with four replicates. All agricultural practice needed to grow the cassava crop was went into practice.

Vegetative growth parameters recorded in data

After 180 days of planting, five plants were randomly selected and labeled in each replicate for each treatment. Plant height, number of leaves per plant, number of main stems per plant, and number of branches were recorded.

Tuber root yield and yield components

Ten months after planting, the tuber roots were harvested in order to measure their length, diameter, weight, and yield.

Chemical composition of tuber roots

- Tuber roots dry matter.
- Starch percent.
- Total fibers percentage.
- Hydrocyanic acid concentration.

Starch percent, total fibers percentage and hydrocyanic acid were as described by Smith and Zeeman (2006), AOAC (1990) and AOAC (1990) and Foda (1987), respectively.

Statistical analysis

Snedecor and Cochran's (1980) description of the analysis of variance method was applied to the data. Treatment means were compared using the Duncan Multiple Range Test at 5% (Duncan, 1955). Analysis of the data was done using the STATISTIX software version 10.0.

2- Towards producing pasta

Several cassava varieties were used in the pasta-making experiment, and the effect of these variations on the final product's acceptability and quality for ingestion were noted.

Materials

We obtained the semolina from the North Cairo Flour Mills Company in Egypt.

Methods

Preparation of flour mixtures

Cassava flour and semolina were thoroughly mixed to produce separate combinations that had 10, 20%, and 30% American, Brazilian, and Indonesian cassava, respectively as shown in Table (1). All samples were stored in airtight containers.

Table 1. Mixture composition for pasta production (g).

Ingredients	Pasta formulas with									
	Control	American Cassava			Brazilian Cassava			Indonesian Cassava		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Semolina	100	90	80	70	90	80	70	90	80	70
Sunflower oil	1	1	1	1	1	1	1	1	1	1
Cassava flour	-	10	20	30	10	20	30	10	20	30

Pasta preparation

Briefly, 200 g Semolina (control) and Semolina replaced with cassava flour at level 10, 20 and 30% was mixed in a mixer bowl for 1 min. Using a laboratory pasta machine (Matic 1000 Simac Machine Corporation, Millano, Italy), pasta samples were made according with AACC (2000). After 15 minutes of hydration in ambient air, the pasta was dried for 10 hours at 70 degrees Celsius in a cabinet dryer (Hussein, *et al*., 2023). After cooling to room temperature, the samples were placed in polyethylene bags and stored for analysis at room temperature.

Cooking quality

Pasta's cooking quality was determined using the AACC (2000) techniques, which measured weight, volume, and cooking loss increases after cooking.

Color determinations

Objective evaluation of color for pasta was measured. Hunter a*, b* and L* parameters were measured with a color difference meter using a Hunter color meter (Tristimulus Colour Machine) with the CIE lab color scale (Hunter, Lab Scan XE - Reston VA, USA) in the reflection mode. The instrument was standardized each time with white tile of Hunter Lab Colour Standard (LX No.16379):

X= 72.26, Y= 81.94 and Z= 88.14 (L*= 92.46; a*= -0.86; b*= -0.16).

Sensory evaluation of pasta

Samples of pasta were prepared in distilled water for the optimum cooking time, drained for two minutes, and then served to the panelists. The sensory test panel consisted of seven panelists who had been trained as academic personnel. Using a 10-point hedonic scale that ranged from 10-5 (like exceedingly) to 4-1 (dislike extremely) for each sensory trait, the panelists assessed the items' color, flavor, mouthfeel, elasticity, and overall acceptability (Hussein, *et al*., 2021).

Textural profile analysis (TPA)

The CT3 Texture Analyzer (Brookfield) was used to analyze the hardness, deformation at hardness, peak stress, and fracture ability of cooked pasta samples with 1% load sensitivity in accordance with Manual No. M08-372-C0113. Using Texture Pro CT software, data was collected.

Statistical analysis

The software SAS Systems for Windows, version 6.12 TS020, was used to statistically analyze the collected data. The analysis of variance (ANOVA) and the least significant difference (LSD) test ($P < 0.05$) were used to determine significant variations between the treatment means.

Results and Discussion

Data in Table (2) showed how planting distances impact the growth of cassava cultivars. The Brazilian cultivar produced the greatest values for plant height, number of leaves, and main stem number. In contrast, the Indonesian cultivar displayed a rise in plant height in comparison to the American cultivar regarding the two seasons. The merican cultivar had more leaves and main stems than the Indonesian cultivar. Concerning, the branches number character, the highest value was recorded in the American cultivar later on Indonesian cultivar, and then Brazilian cultivar in both seasons. The way that each variation branches naturally influences how differently each cultivar grows. The cultivar with the least amount of branching records the maximum height, whiles the cultivar with the most branching decreases in height. On potato, this phenomenon agrees by Mangani *et. al*. (2015). In relation to plant spacing, studding discovered that during the duration of the two seasons, the biggest distance between plants (100 cm) recorded greater values of vegetative growth characteristics than the shortest one (75 cm), Table (2). This might be because photosynthesis is happening at a faster rate and more light is getting to the plants, which increases growth metrics including plant height, number of leaves, main stem number and branches number (Muneer, *et. al*., 2017). This result agrees with the findings of Ara *et al*. (2007), they noticed that higher tomato plants were associated with greater.

Table 2. Impact of planting distances, cultivars, and their combination on the vegetative growth of cassava 180 days post-planting in 2022/23 and 2023/24.

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Treatments		Plant height (cm)		Leaves number		Main stems number		Branches number	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Effect of Cultivars									
Indonesian		241.3^{B}	247.5^{B}	108.6^{C}	104.4^{C}	2.4^{C}	3.0^{B}	5.3^{B}	5.7^{B}
Brazilian		247.6^{A}	257.5^{A}	215.2^{A}	210.9^{A}	3.9^{A}	4.3^{A}	2.6^{C}	3.1^{C}
American		200.4 ^{C}	206.5^{C}	119.5^{B}	112.4^{B}	3.3^{B}	3.2^{B}	14.1^{A}	14.0^{A}
Effect of planting distances									
75 cm		210.1^{B}	220.1^{B}	114.0^{B}	115.0^{B}	2.9^{B}	2.9^{B}	6.6^{B}	6.3^{B}
100 cm		249.4^{A}	254.2^{A}	181.5^{A}	170.1^{A}	3.5^{A}	3.5^{A}	8.0^{A}	8.9^{A}
Effect of interaction									
Indonesian	**75 cm**	230.2^{C}	240.5^{B}	81.5^{E}	87.4^{E}	2.1^{E}	2.9^{E}	4.9^{D}	5.1^{D}
	100 cm	252.3^{B}	254.4^{B}	135.6^{C}	121.4^{C}	2.7^{D}	3.1^{D}	5.7^{C}	6.3^{C}
Brazilian	**75 cm**	230.0^{C}	241.7^{B}	160.0^{B}	156.3 ^{B}	3.6^{B}	3.9^{B}	2.3^{E}	2.5^{E}
	100 cm	265.1^{A}	273.2^{A}	270.4^{A}	265.4^{A}	4.1^{A}	4.7^{A}	2.8^{E}	3.7^{E}
American	**75 cm**	170.0^{D}	178.0^{D}	100.5^{D}	101.3^{D}	2.9^{C}	2.9^{E}	12.5^{B}	11.3^{B}
	100 cm	230.7^{C}	235.0^{C}	138.5^{C}	123.5^{C}	3.6^{B}	3.5^{C}	15.6^{A}	16.7^{A}

According to Duncan's Multiple Range Test, numbers in the same column that are followed by the same letter or letters do not differ significantly at the 5% level.

Regarding, the interaction between varieties and distances, data in Table 2, indicated that in the 2022–2023 and 2023–2024 seasons, the American cultivar and a 100 cm distance increased the number of branches, while the Brazilian cultivar and same distance gave an increase in plant height, leaves, and main stems. The lower results varied depending on the parameters that were researched between cultivars. For instance, plant height less at a distance of 75 cm and American cultivar, while branches number decreased with the Brazilian cultivar at 75 or 100 cm distance in two seasons. Leaves and main stems number decreased with the Indonesian cultivar at 75 cm distance.

Table 3 is result showed how significantly different numerous cassava varieties' yield quality and yield were from one another. The longest tuber roots were produced by Indonesians, second by Brazilians, and finally by Americans. As for the tuber roots diameter, tuber roots weight, and yield was widest diameter, heavier weight, and largest yield, respectively, with the American followed by the Brazilian and then the Indonesian during 1st and 2nd seasons. Measurements of cassava showed a substantial difference in relation to planting distance. In two seasons, the tuber roots' length, diameter, weight, and yield were higher at 100 cm distance than at 75 cm distance (Table 3).

Table 3. Impact of planting distances on quality and yield cassava cultivars at time harvesting after planting during 2022/23 and 2023/24

Treatments		Tuber roots length (cm)		Tuber roots diameter(cm)		Tuber roots weight (gm)		Yield/ fed. (ton)	
		1st season	2nd season	1st season	2nd Season	1st season	2nd Season	1st season	2nd Season
Effect of Cultivars									
Indonesian		36.0A	32.2A	3.5C	3.4B	300.1C	282.6C	7.6C	6.4C
Brazilian		31.0B	32.8A	3.8B	3.7B	472.2B	444.8B	11.9B	10.9B
American		27.6C	28.5B	4.8A	5.3A	509.9A	504.5A	16.4A	15.5A
Effect of planting distances									
75 cm		29.7B	31.0A	3.8B	3.9B	421.4B	402.6B	10.5B	9.3B
100 cm		33.3A	31.3A	4.2A	4.2A	433.4A	418.6A	13.4A	12.5A
Effect of interaction									
Indonesian	**75 cm**	35.4A	35.4A	3.7D	3.2D	298.7F	277.6F	5.7E	4.2F
	100 cm	28.9D	28.9D	3.7D	3.5C	301.5E	287.6E	9.5D	8.6E
Brazilian	**75 cm**	31.2C	31.2C	3.9C	3.5C	456.7D	432.7D	11.2C	10.3D
	100 cm	34.4B	34.4B	4.6B	3.8B	487.7C	456.8C	12.6C	11.4C
American	**75 cm**	26.5E	26.5E	3.7D	5.1AB	508.8B	497.6B	14.5B	13.4B
	100 cm	30.5C	30.5C	4.9A	5.4A	510.9A	511.3A	18.2A	17.5A

According to Duncan's Multiple Range Test, numbers in the same column that are followed by the same letter or letters do not differ significantly at the 5% level.

The plants may be robust at a large distance because there is less competition for the nutrients, which could lead to the best result. This outcome is similar to the findings of Rahman and Talukdar (2003) on garlic and Robert *et al.* (2015) on potato.

Regarding to interaction between cultivars and planting distances of cassava in the two seasons, results in Table 3 indicated that the Indonesian cultivar with 75 cm distance recoded the longest tuber roots of cassava, while the American cultivar with 75 cm distance gave shortest tuber roots during the two seasons. Tuber roots diameter, weight, and yield increased with American cultivar and at 100 cm distance compared to Indonesian cultivar and 75 cm one in the two seasons. The treatment that included the American cultivar at 100 cm distance increased the yield by 73.0 – 76.0% compared to treatment of the Indonesian cultivar at 75 cm distance in 1st and 2nd seasons, respectively.

According to Table 4's data, the American cultivar produced the highest value for the percentage of dry matter and starch in tuber roots, followed by the Brazilian and then Indonesian in both 2 seasons, while the fiber percentage, and hydrocyanic acid increased in the Indonesian followed by the Brazilian then the American during the two years of study.

In generally, the Brazilian cultivar is considered middle between the American and the Indonesian in the measured characters readings for cassava plants. In connection with, planting distance 100 cm recorded higher value compared to 75 cm regarding to tuber roots dry matter and starch percentage, whereas, fibers % and hydrocyanic acid was increment at 75 cm distance in Table 4 during 1st and 2nd seasons. The tuber roots dry matter percentage increases with the wide distance between plants. On potato, Mutetwa (2010) stated the same result.

The effect of interaction between cassava cultivars and planting distance on chemical in Table 4 showed that the American cultivar at 100 cm distance gave the highest results, and the Indonesian at 75 cm distance gave a lower result for tuber roots dry matter, and starch percentage. The opposite is true for fibers % and hydrocyanic acid in the two seasons. These cultivars that cultivated in narrow distances compete on added fertilizer for nutrition, unlike those that live in wide distances.

So, the plants located in wide distances give higher results as tuber roots dry matter and starch percentage and lower in fibers percentage and hydrocyanic acid (Getachew *et al.*, 2013).

Table 4. Impact of planting distances on chemical cassava cultivars during 2022/23 and 2023/24.

Treatments		Tuber roots dry matter percentage		Starch percentage		Fibers percentage		Hydrocyanic acid (ppm)	
		1st season	2nd season	1st season	2nd season	1st Season	2nd season	1st season	2nd season
Effect of Cultivars									
Indonesian		31.8C	30.2C	65.8C	63.2C	2.3A	2.4A	49.9A	47.7A
Brazilian		38.8B	38.2B	73.8B	73.3B	1.8B	1.8B	43.2B	40.3C
American		44.6A	44.6A	76.8A	75.8A	1.5C	1.5C	39.9C	41.0B
Effect of planting distances									
75 cm		36.9B	35.3B	70.6B	69.5B	1.9A	2.0A	47.6A	46.9A
100 cm		39.8A	40.1A	73.6A	72.0A	1.8B	1.8B	41.0B	39.0B
Effect of interaction									
Indonesian	**75 cm**	29.8F	27.8F	63.2E	62.1E	2.32A	2.56A	54.3A	52.2A
	100 cm	33.7E	32.6E	68.4D	64.3D	2.29AB	2.32AB	45.5C	43.2C
Brazilian	**75 cm**	37.7D	36.6D	73.2C	72.3C	1.87 B	1.89B	46.5BC	43.2C
	100 cm	39.8C	39.8C	74.3BC	74.3B	1.64C	1.76C	39.8E	37.3D
American	**75 cm**	43.3B	41.4B	75.4B	74.2B	1.57D	1.54D	42.1D	45.4B
	100 cm	45.8A	47.8A	78.1A	77.3A	1.45E	1.39E	37.6F	36.5E

According to Duncan's Multiple Range Test, numbers in the same column that are followed by the same letter or letters do not differ significantly at the 5% level.

Correlation between certain tuber root characteristics and the total yield of fresh tuber roots in cassava Table 5 and Figs (1 & 2) lists every potential correlation coefficient between the total yield of fresh tuber roots produced by cassava and a few tuber root characteristics. According to these findings, a significantly substantial and positive correlation was observed ($P < 0.01$) between the fresh tuber root total yield in cassava, and the parameters of tuber root diameter, weight, dry matter percentage, and starch percentage in both seasons. This is typical, as a larger yield is produced when the diameter of the tuber roots increases, their weight increases, and thus the dry matter content increases. Also, when the cassava plant is harvested produced when the diameter of the tuber roots increases, their weight increases, and thus the dry matter content increases.

Table 5. Values of Person's correlation coefficient at harvest time between the total output of cassava and some characteristics of the tuber roots in 2022/23 and 2023/24 seasons.

Characters	Total yield /fed. (ton)	
	Season 2022/23	Season 2023/24
Tuber roots length (cm)	-0.579 ns	-0.546 ns
Tuber roots diameter (cm)	0.789 **	0.904 **
Tuber roots weight (gm)	0.877 **	0.905 **
Tuber roots dry matter %	0.987 **	0.993 **
Starch percent	0.963 **	0.923 **
Total fibers percentage	-0.938 *	-0.964 *
Hydrocyanic acid (ppm)	-0.932 *	-0.788 *

(**) indicates significance at 1%, (*) indicates significance at 5%, and (ns) indicates non-significant at 5%.

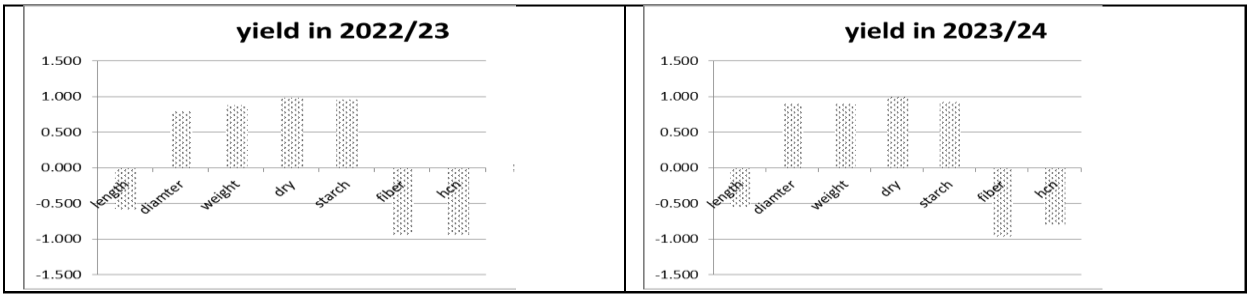

Fig. 1. Person's correlation coefficient showed at harvest time between the total output of cassava and some characteristics of the tuber roots in the 2022/23 and 2023/24 seasons

Also, when the cassava plant is harvested at the right time, a high quality starch-like crop is produced. In addition, over the course of two seasons, a significant and negative correlation (P < 0.05) was found between the total yield of fresh tuber roots between fiber %, and hydrocyanic acid concentration of the tuber roots. This results from harvesting at the proper time, which lowers the production of hydrocyanic acid and fibers on cassava plant. Additionally, there is a negative and non-significant association (P < 0.05) between the total yield of fresh tuber roots and tuber roots length in two seasons. This is logical, because when the root length is long and its diameter is small, the same weight is given to the short root length and its large diameter, and thus the yield does not record significant differences.

Color parameters of pasta samples:

The relationship between color and expectations for product freshness and flavor makes it one of the most significant quality attributes for food acceptability and, consequently, it directly influences how customers perceptions. Pasta products with color have been more popular in recent years because to their beneficial effects on customers. However, the use of natural colorants has the advantage of being widely accepted by consumers, regarded as safe, and not chemical, as resistance to the use of synthetic colorants in foods is increasing. All the cooked and uncooked pasta samples' color values are shown in Tables 6 and 7.

Table 6. Uncooked pasta color parameters.

Samples	L*	a*	b*	a/b	Saturation	ΔE
Semolina 100%	74.05±0.65	2.32±0.03	17.68±0.15	0.10±0.001	17.83±0.12	77.54±0.28
90% S +10% AC	73.6±0.62	2.28±0.05	22.48±0.17	0.09±0.01	22.60±0.22	77.79±0.26
80% S +20% AC	68.62±0.54	2.52±0.04	19.1±0.19	0.10±0.02	19.27±0.18	73.12±0.35
70% S +30% AC	75.05±0.55	2.31±0.03	16.87±0.13	0.09±0.003	17.03±0.19	79.74±0.40
90% S + 10% BC	71.48±0.45	3.24±0.02	21.71±0.12	0.12±0.006	21.95±0.17	76.63±0.45
80% S + 20% BC	69.23±0.35	3.67±0.01	19.44±0.17	0.12±0.002	19.78±0.15	75.37±0.49
70% S + 30% BC	72.98±0.42	3.23±0.02	16.7±0.19	0.12±0.003	17.01±0.12	78.87±0.51
90% S + 10% IC	68.87±0.60	3.02±0.04	21.41±0.13	0.12±0.004	21.62±0.20	73.27±0.53
80% S + 20% IC	69.56±0.58	2.78±0.07	18.96±0.11	0.11±0.001	19.16±0.21	73.85±0.55
70% S + 30% IC	70.23±0.68	2.49±0.05	16.66±0.14	0.11±0.005	16.85±0.13	73.57±0.62

S = Semolina, AC = American Cassava, BC = Brazilian Cassava, IC = Indonesia Cassava

Table 7. Cooked pasta color parameters.

Samples	L*	a*	b*	a/b	Saturation	ΔE
Semolina 100%	62.75±0.35	0.53±0.03	18.64±0.28	0.03±0.0	18.65±0.22	65.46±0.35
90% S +10% AC	53.63±0.22	1.76±0.05	14.31±0.12	0.123±0.01	14.42±0.25	55.53±0.39
80% S +20% AC	58.39±0.14	2.93±0.12	13.48±0.56	0.22±0.02	13.79±0.18	59.99±0.42
70% S +30% AC	58.93±0.30	3.4±0.124	14.72±0.03	0.23±0.003	15.11±0.21	60.84±0.45
90% S + 10% BC	62.94±0.53	2.01±0.07	17.41±0.07	0.12±0.01	17.53±0.20	65.33±0.36
80% S + 20% BC	61.37±0.25	2.87±0.05	13.9±0.05	0.21±0.01	14.19±0.17	62.99±0.52
70% S + 30% BC	57.32±0.29	4.43±0.15	12.69±0.15	0.35±0.02	13.44±0.24	58.87±0.55
90% S + 10% IC	58.32±0.45	2.6±0.09	13.45±0.17	0.19±0.03	13.70±0.19	59.91±0.49
80% S + 20% IC	59.4±0.38	2.27±0.10	15.53±0.13	0.15±0.01	15.70±0.22	61.44±0.39
70% S + 30% IC	62.75±0.35	0.53±0.03	18.64±0.28	0.03±0.0	18.65±0.22	65.46±0.35

S = Semolina, AC = American Cassava, BC = Brazilian Cassava, IC = Indonesia Cassava

Pasta color is an important factor whenevaluating its quality. In general, customers want pasta that is bright yellow in colour (Debbouz *et al*., 1995). The lightness (L* value) of the uncooked pasta samples did not differ significantly (P < 0.05). However, as the amount of cassava flour increased, the cooked pasta samples became lighter. The raw and cooked pasta samples' redness (a* value) yielded similar results. As the amount of cassava flour increased, it led to an increase pasta redness. The rise in sugars from the cassava flour levels may be the cause of the redness increase and could contribute to the caramelization response (Oyeyinka *et al*., 2018). There were significant differences in the yellowness (b*value) of the pasta made with varying amounts of cassava flour in both the raw and cooked samples. The cooking process bleached all pasta samples, increasing their brightness and decreasing their redness and yellowness (Petitot *et al*., 2010). As expected, the color of enriched pasta products showed an increase in darkness (L*). The control pasta had the lowest b* value (17.68) due to the high white pigment concentration of cassava flour. Because the enriched pasta was yellower and brighter after cooking, color losses were seen. Data in table (6) revealed that, pasta color significantly decreased in pasta of different cassava flour mixing levels, this result is supported by earlier color parameters (L, a, and b), which showed that darkness rose as cassava flour replacement increased. However, the diffusion of the pigments into cooking water was slightly detected visually.

Pasta cooking Quality:

Cooking quality is the ability of cooked pasta maintain its textural qualities at the optimum cooking term (Del Nobile *et al*., 2005). Cooking characteristics including weight rise, cooking loss and volume increase could be used to determine the quality of pasta. The weight and volume increase of pasta supplemented with cassava flour ranged from 220 to 280% and from 175 to 250%, respectively. The findings indicated that, as compared to the control sample, an increase in weight and volume was noted with varying amounts of cassava flour (Table 8). The weight of cooked pasta may have increased as a result of the cassava flour's decreased protein content. As the amount of cassava flour increased cooking losses rose. The ability of the gluten and cassava flour proteins to strengthen the dough matrix and trap starch inside the resulting network may be the cause of this outcome. The amount of dry matters lost into the cooking water is indicated by this value. Cacak-Pietrzak *et al*. (1997) showed that the cooking losses of various semolina-based pasta varieties varied from 6 to 11%. In the present study, cooking loss of control pasta and pasta with FE or FT were found to be 1.33, 1.36 and 1.35%, respectively. The cooking loss in all the pasta samples was below the technologically acceptable limit (≤8%). There were no significant differences in cooking loss among the groups ($P > 0.05$); thus, it can be said that the cooking loss was unaffected by the addition of cassava flour at these amounts.

Table 8. Impact of adding cassava flour on pasta's cooking quality.

Samples	Weight increase (%)	Volume increase (%)	Cooking loss (%)
Semolina 100%	220±1.11	175±2.20	7.5±0.19
90% S +10% AC	240±1.42	200.00±2.75	8.5±0.25
80% S +20% AC	250±2.15	212.50±2.65	10.5±0.35
70% S +30% AC	255±2.25	218.75±2.50±2.50	13.0±0.42
90% S + 10% BC	250±1.55	212.50±1.75	9.0±0.22
80% S + 20% BC	270±2.20	237.50±2.25	11.0±0.30
70% S + 30% BC	280±2.45	250.00±2.50	13.0±0.45
90% S + 10% IC	260±2.15	225.00±2.20	8.0±0.35
80% S + 20% IC	265±2.35	231.25±2.35	10.0±0.40
70% S + 30% IC	270±2.42	237.50±2.45	13.5±0.45

S = Semolina, AC = American Cassava, BC = Brazilian Cassava, IC = Indonesia Cassava

Sensory properties:

The organoleptic characteristics of pasta made with semolina and cassava flour added in varying amounts (10, 20, and 30%) were assessed for appearance, color, flavor, tenderness, and stickiness in Table (9) and illustrated in Fig.(3). Table (9) revealed that, the previously stated color parameter confirms that pasta color significantly decreased when cassava flour mixing quantities were varied. (L, and b) where the degree of darkness increased as wheat flour replaced cassava flour. However, adding up to 30% more cassava flour did not significantly change the stickiness of the control pasta.

One of the most important criteria of pasta quality is tenderness. The sensory results showed that, in comparison to the control sample, the tenderness and appearance of pasta enriched with 10 and 20% cassava flour were not significantly impacted, However, pasta made with 10% cassava flour showed no significant alteration in flavor. It was clear from the data shown in Tables (9) that the sensory qualities reduced as the amount of cassava flour added increased. Cassava flour can be added to pasta at amounts of 10% or 20% without negatively affecting the product's sensory acceptability.

Table 9. Evaluation of cooked pasta using the sensory.

Samples	Appearance (10)	Color (10)	Flavor (10)	Tenderness (10)	Stickiness (10)
Semolina 100%	9.1^{a}	9.3^{a}	9.5^{a}	9.5^{a}	9.3^{a}
90% S +10% AC	8.5^{a}	8.2^{b}	9.1^{a}	8.8^{b}	9.1^{a}
80% S +20% AC	7.3^{b}	8.0^{c}	8.5^{b}	8.1^{c}	8.7^{b}
70% S +30% AC	6.2^{c}	7.1^{d}	8.3^{b}	7.5^{d}	8.2^{c}
90% S + 10% BC	8.4^{a}	8.5^{b}	8.5^{b}	8.7^{b}	8.5^{b}
80% S + 20% BC	8^{b}	8.1^{c}	8.5^{b}	8.4^{c}	8.1^{c}
70% S + 30% BC	7.6^{b}	7.6^{d}	8.0^{c}	7.6^{d}	7.8^{c}
90% S + 10% IC	8.4^{a}	8.6^{b}	8.5^{b}	8.7^{b}	8.7^{b}
80% S + 20% IC	7.8^{b}	7.1^{d}	8.1^{c}	8.0^{c}	8.5^{b}
70% S + 30% IC	6.7^{c}	6.5^{e}	8.1^{c}	7.8^{d}	7.6^{d}
LSD	0.531	0.325	0.311	0.466	0.419

S = Semolina, AC = American Cassava, BC = Brazilian Cassava, IC = Indonesia Cassava

Fig. 3. pasta supplemented with cassava flour.

Conclusion

Through the data obtained from the study, we found that the American cultivar gave the highest value in most of the studied characters of the cassava plant, such as branches number, tuber roots diameter, weight, yield, tuber roots dry matter, and starch percentage, in contrary it recorded lowest result for fibers % and hydrocyanic acid. The appropriate distance between cassava plants is at 100 cm distance. Therefore, the recommendation was to use the American cultivar at 100 cm planting distance. According to our research, semolina and cassava flour could be used to make pasta with improved technological qualities, a higher nutritious content, and acceptable sensory qualities. Additionally, the products improved lean body mass and basal metabolic rate. Overall, the findings indicated that 10% or 20% cassava flour can be added to pasta without negatively affecting its sensory acceptability. These products may be very beneficial for obese individuals and athletes.

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