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Factors Related to the Starch Content during the Extraction Process of Cassava (*Manihot Esculenta*, Crantz) Crop

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Abstract

The objective of this article was to determine the factors that affect the% starch during the extraction process from the cassava crop (*Manihot esculenta*, Crantz). The material used corresponded to the commercial varieties "Concha Rosada" and "Llavitera", harvested at 9 and 11 months, using a 25-1 fractional factorial design, considering 16 observations, where the effect of 5 factors on the% starch was evaluated: crop variety, harvest time, type of cleaning (manual and mechanized), volume of water used in the leaching process and grinding speed; applying the analysis of variance through the statistical R program. A significant effect ($p \leq 0.05$) of the cutting speed factor was found, in addition to the interactions variety of cassava * amount of water in the leaching process and amount of water in the process leaching*harvest time; Four factors were selected: cassava variety, harvest time, amount of water in the leaching process and milling speed, as the predominant factors in the cassava starch extraction process. The application of the 2^{K-1} fractional factorial design allowed us to select the factors of cassava variety, grinding speed, amount of water used in the leaching process and harvest time, from the total factors initially addressed.

Keywords: 2^{K-1} Factorial design, Controllable factors, Interaction, Starch, Cassava, extraction.

Introduction

Cassava (*Manihot esculenta* Crantz) cultivation is of great importance for food security and is considered the fourth most important commodity after rice, wheat and corn; becoming a basic component in the diet of more than 1 billion people, as noted by the (FAO, 2006). In recent years, cassava has been considered a very competitive crop, due to the starch content present in the root, being almost better than any other food crop, which in the opinion of Parmar et al., (2017) it is more viscous and stable in acidic food products than most tubers; Furthermore, its starch shows potential for the development of products with high added value in food and non-food industrial applications such as pharmaceuticals, paper, fabrics, sweeteners, biofuels and even the manufacture of bioplastics. Tropical countries annually import corn starch and its derivatives at a high cost, and in many countries it can be substituted with local cassava starch, and even with good quality cassava flour. In this sense, in Latin America and the Caribbean, the production of cassava starch has been concentrated in Brazil and Colombia, almost all of it produced in small and medium-sized

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industries, with intensive labor and traditional techniques, as pointed out by (Orojloo, 2019; Branco et al., 2020; Abbasi et al, 2021). Cassava production in Venezuela has had advantages, due to its high yield per hectare, tolerance to drought and degraded soils; This has allowed the production of starch in an artisanal and semi-industrial way in some rural communities, with intensive labor and traditional techniques, with the exception of some modern agro-industries located in the east of the country.

In this sense, various studies have been carried out in order to optimize and standardize the starch extraction process on an artisanal and semi-industrial scale, and make it a sustainable model in view of current trends in the consumption of quality alternative foods healthy, as mentioned by (Torres et al., 2010). Likewise, authors such as García et al., (2018) carried out studies to determine the best starch extraction conditions, focused mainly on the volume of water required in the leaching phase for a higher yield. On the other hand, Olusola et al., (2015) evaluated the yield of% starch in different varieties of cassava and harvest times, in order to adapt the best conditions for its extraction. Likewise, Saengchan et al., (2015) studied the effects of cassava pulp particle size and root variety on starch extraction and quality. Consequently, these studies have focused their efforts on improving the performance of starch extraction, in order to encourage the productivity of the cassava crop and improve income, translating into a better quality of life for producers. In this sense, the objective of this study was to determine the factors that affect the starch content during the extraction process from cassava (*Manihot esculenta* Crantz), by using a 2^{5-1} fractional factorial design.

Material and Methods

The research was carried out in a semi-mechanized agroindustry, in a plot located in the Santa Rita area, Francisco Linares Alcántara Municipality, Aragua state, Venezuela. Two commercial cassava cultivars were used: Concha Rosada and Llavitera, harvested at 9 and 11 months. Table 1 shows the factors evaluated in the starch extraction process from the cassava crop. The response variable that was measured was the% starch present in the roots and its determination was made by the method of the specific gravity of the roots, established by Toro y Cañas (2002) with the following formula:

$$GE=PFRA/(PFRA-PFRAg)$$

where:
GE: Specific Gravity
PFRA: Fresh weight of roots in air
PFRAg: Fresh weight of roots in water

Table 1. Factors evaluated in the cassava (*Manihot esculenta* Crantz) starch extraction process.

Factor	Level	Units
Cassava variety (A)	Concha Rosada and Llavitera	-
Grinding speed (B)	1200 and 1400	rpm

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Amount of water in the leaching process (C)	450 and 700	Kg of water / Kg of cassava pulp
Cleaning Type (D)	Manual and semi-industrial	-
Harvest time (E)	9 and 11	Months

2^{K-1} fractional factorial design.
A 2^{5-1} fractional factorial design was used, where the effect of five (5) factors on the% of starch from cassava was evaluated, this being one of the variables measured at the end of the starch extraction process from the Yucca. The application of a 2^{5-1} fractional factorial design implied the use of the fraction ½, therefore, 16 combinations of the 32 possible ones are required; To construct this fraction, a single design definition relationship was used, which was I = + ABCD, obtained by selecting only the combinations of treatments that have a positive sign in the ABCDE column, according to (Lorenzen and Virgil, 1993). The resolution of the 2^{5-1} design is V, indicating that none of the main effects or first-order interactions are aliases to another main effect or first-order interaction, but Two-way interactions are aliases for three-way interactions. This aliased structure of the main effects and interactions allows a good interpretation of the data, according to (Montgomery, 2004).

Results and discussion

Interaction variety of cassava (A) with amount of water in the leaching process (C)

In Table 2, there is a significant effect ($p \leq 0.05$) for the interaction between the variety factors (A) and the amount of water used in the leaching process (B), this significant effect allows establishing that the Cassava variety is affected by the amount of water used in the extraction process, which means that the percentage of starch obtained will depend on the action of these factors.

Table 2. Analysis of variance on % starch.

Factor	F	P
Cassava variety (A)	357,30	0,0001 *
Grinding speed (B)	24,55	0,0010 *
Amount of water in the leaching process (C)	9,64	0,0150 *
Cleaning Type (D)	0,01	0,9750 ns
Harvest time (E)	44,79	0,0001 *
Variety *Amount of water in the leaching process (A*C)	15,92	0,0040 *
Amount of water* Harvest time (C*E)	5,29	0,0500 *

*: significant differences at 5%

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ns: non-significant differences at 5%

In Figure 1 the interaction effect between these factors is clearly shown, where it is observed that when using the Concha Rosada variety in the starch extraction process, the amount of water is decisive in the performance of this process, obtaining a greater quantity of starch with 450 Kg of water / Kg of cassava pulp (highest level of factor C); However, when using the Llavitera variety, the behavior is not maintained with both water levels, since when using 450 and 700 Kg / Kg of yucca pulp, a similar value was obtained in the% starch, this level being higher than that found in the Concha Rosada variety. Genetic variability causes content ranges to appear in some important components of the root, this being the case of starch. Studies carried out by Olusola el at., (2015), who evaluated four elite clones in six locations and found that starch yield varied depending on the genotype. In this case, it was observed how the Llavitera cultivar significantly surpasses the Concha Rosada variety, giving evidence that the% starch extracted is determined by the variety of the crop. Likewise, Del Rosario et al., (2020), evaluated the industrial performance of 3 local varieties, achieving the highest starch extraction in the MMEXV40 variety, thus demonstrating the effect of the variety on the% starch extracted. Regarding the amount of water used in the leaching process, authors such as Branco et al., (2020) established that effectively the volume of water used in the leaching process significantly influences the final value of the extracted starch; However, an excessive use of the volume of water does not guarantee a greater extraction of starch in this process, but it would directly affect production costs.

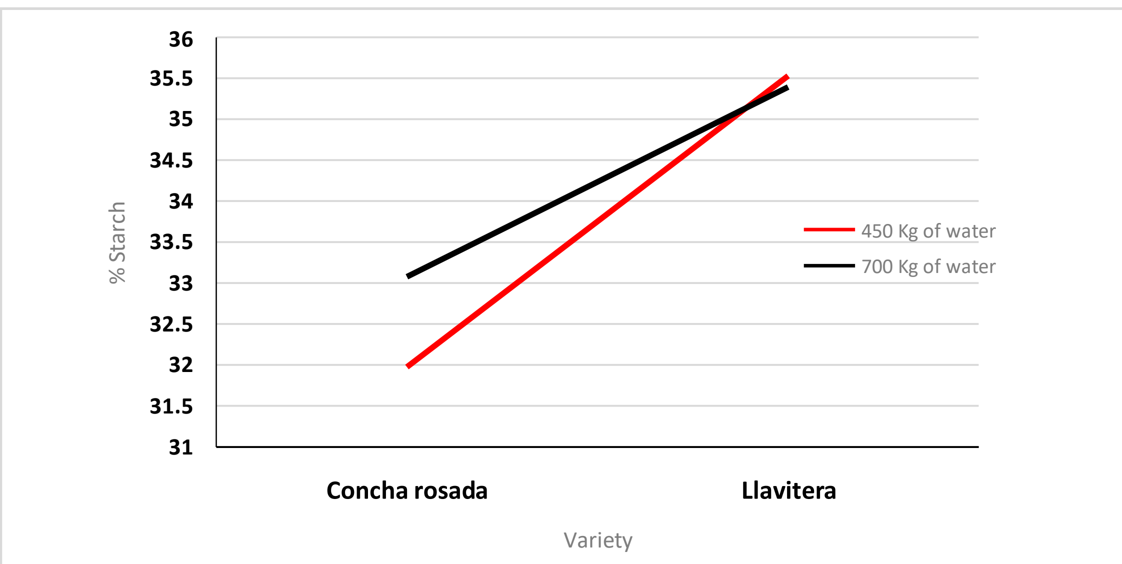

Figure-1: Interaction effect between cassava variety (A) and amount of water in the leaching process (C).

Interaction amount of water in the leaching process (C) and harvest time (E)

In Figure 2 it is observed that the% of starch extracted from cassava depends on the harvest time and the amount of water used in the leaching process. Likewise, it is visualized that when going from a water level of 450 Kg to a level of 700 Kg, the% starch increases in the

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pulps of yuccas harvested at 9 and 11 months respectively, this increase being significant and higher when starch is extracted with roots harvested at 9 months. These results coincide with what was indicated by Fuenmayor et al., (2012), regarding the variation in the content of dry matter and starch in different varieties, who determined that the starch yield depends on the age at which the crop is harvested, obtaining the best yields at 9 months, since increasing the cutting time tends to favor the% fibers, affecting the quality of the final product. On the other hand, García et al., (2018) obtained optimal water values for the extraction of ground cassava starch between 450 kg to 740 kg water / kg of cassava pulp respectively, considering that the solid stream retains the highest amount of inert and the liquid stream (extraction) contains the highest concentration of starch and the lowest of inert, contributing to subsequent separation and purification processes.

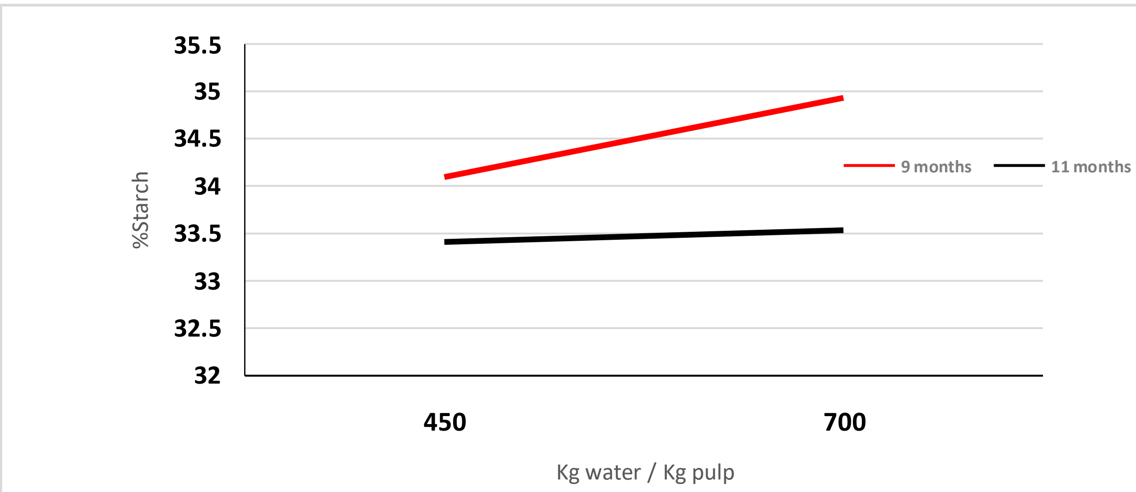

Figure-2: Interaction effect between amount of water in the leaching process (C) and harvest time (E).

Main effects

Grinding speed factor (E)

With respect to the cutting speed in Table 2 it is evidenced that this effect was significant ($p \leq 0.05$), so it is established that depending on the cutting speed that is used, this will be the starch values that will be obtained. Figure 3 shows that the highest% starch values are obtained when using a grinding speed of 1,200 rpm, significantly exceeding the starch content generated when using a speed of 1,400 rpm, which allows establishing that an increase in the Shear speed does not necessarily translate into increased starch content extraction. This behavior coincides with that reported by Branco et al., (2019) who pointed out that excessive grinding generates very small starch granules, suffering physical damage and subsequent enzymatic deterioration; causing the sedimentation to be slower since the fine granule loses density, in addition to the formation of more stains in the final product. It should be noted that the efficiency of this operation determines, to a large extent, the total starch yield in the extraction process, as indicated by Torres et al., (2014).

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Cleaning type factor (D)

When evaluating the type of manual cleaning against semi-industrial cleaning (Table 2), no significant differences (p> 0.05) were found between these evaluated levels, so regardless of the type of cleaning used to remove soil and impurities adhered to the roots, the starch content will be similar in both methods. In this sense, the importance of the use of the semi-industrial cleaning system is highlighted, since the application of this method translates into a reduction in the time used and decrease in the losses of pulp (raw material), without affecting the quality of the Final product; thus achieving greater profitability in terms of time and costs.

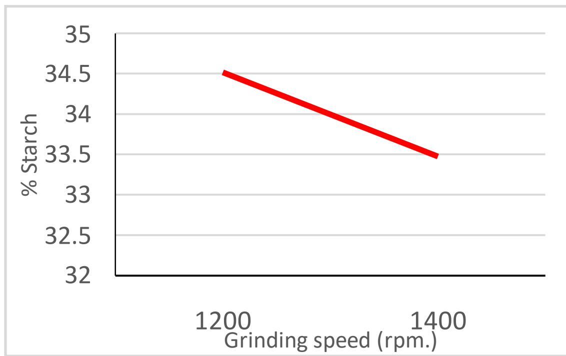

Figure-3: Average starch% values obtained at grinding speeds of 1,200 and 1,400 rpm, respectively.

Conclusion

Finally, based on the results obtained in the present investigation, with the application of the fractional factorial experiment 25-1 it was possible to determine that the factors that significantly affect the starch extraction process in cassava cultivars are: cassava variety (A), grinding speed (B), amount of water used in the leaching process (C) and harvest time (E); which should be considered when seeking to optimize the cassava starch extraction process. This result shows the importance of implementing fractional factorial designs in process where several factors intervene, since with the use of a fraction of the complete experiment it is possible to know the action of each factor on the process, selecting those that significantly intervene, reducing the costs of experimentation and saving execution time.

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