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**Research Article**

# Effect of Maltodextrin and Gum Arabic Concentration on the Rheological Behavior of Sapote (*Calocarpum sapota* Merr) Pulp

[1]Oscar J. Mendoza-Palencia, [1]Omar A. Pérez-Sierra, [2]Ramiro Torres-Gallo, [1]Fabián A. Ortega-Quintana, [1]Everaldo J. Montes-Montes and [1]Ricardo D. Andrade
[1]Department of Food Engineering, Universidad de Córdoba, Montería, Colombia
[2]Department of Agro-Industrial Engineering, Universidad del Atlántico, Barranquilla, Colombia

**Abstract:** The aim of this research was to measure the effect of maltodextrin and gum Arabic on the rheological behavior of the sapote pulp. The rheological behavior of fruit pulp is modified with the addition of encapsulants which in turn influences the energetic performance of spray drying. In such processes, both maltodextrin and gum arabic are used as encapsulants of fruit pulp and acting as sugars protectors and thus reducing caramelization reactions. The experiment was conducted under a completely randomized design with 2×4 factorial arrangements (Factors: encapsulants and concentration). A Rheometer (AR 1500ex) was used for conducting the flow trials on continuous ramp on the pulp with encapsulants concentrations of 15, 20, 25 and 30% (w/w). Ostwald de Waele's model was adjusted to apparent viscosity data with determination coefficients greater than 0.994, apart from that, the consistency index (k) and the flow behavior index (n) showed significant differences ($p \leq 0.05$) between encapsulants and concentrations used. Those *n* values lower than one characterize the encapsulated pulp as pseudoplastic flow and the presence of hysteresis among the ascending and descending curves indicate that this is time-dependent fluid with thixotropic nature. The apparent viscosity of the pulp increased with the rise in the encapsulants concentration for the same shear rate, being the gum arabic the one with the greater values. Results will contribute to the improvement of the pump systems design of spray dryers.

**Keywords:** Apparent viscosity, consistency index, encapsulant, flow behavior index, power law, thixotropic

## INTRODUCTION

Sapote (*Calocarpum sapota* Merr) is a native fruit from Central America where it is widely grown. Its presence is also common in the Caribbean, Venezuela, Colombia and Ecuador and it has been acclimatized in the Philippines and Hawaii as well (Geilfus, 1994). Sapote belongs to the *Sapotaceae* family and it is taxonomically referred to as *Pouteria sapote* (Jacquin) H.E. Moore &Stearn (Azurdia, 2005).

The sapote pulp is sweet, soft and smooth scent with characteristic flavor (Azurdia, 2005). With a 32.88% of carbohydrates (Simanca *et al*., 2002), the highest percentage of soluble solids (24.6°Brix) among the fruits grown in the department of Cordoba (Colombia) and a pulp yield of 44.82% (w/w), sapote stands as one of the most promising species to be industrialized (Villalva *et al*., 2006).

In the industrial processes of sapote it is necessary to understand the rheological behavior of the pulp in order to control variables of a process as well as equipment design such as pumps, stirring systems and heat exchangers (Queiroz *et al*., 2000; Andrade *et al*., 2009b; Quek *et al*., 2013; Ortega *et al*., 2015).

Maltodextrin (MA) and Gum Arabic (GA) are encapsulating additives used during the spray drying of fruit pulps to reduce the loss of nutritional and functional compounds such as vitamin A, vitamin C, flavors and scents which are eliminated in the process because of the high temperatures used during the process. Besides, encapsulants increase the glass transition temperature and avoid the caking effect caused by the high sugar content of the pulp and creating a protective layer on the food matrix which in turn prevents caramelization reactions during the process. However, it is worth mentioning the addition of encapsulants on the pulp has influence over the mixture apparent viscosity caused by the rise of total solids in the mixture.

Most fruit pulps are non-Newtonian fluids whose apparent viscosity decreases along with the shear rate (Andrade *et al*., 2010). In order to predict the rheological behavior of these pulps, a number of mathematical models are used, being the power law

**Corresponding Author:** Oscar J. Mendoza-Palencia, Department of Food Engineering, Universidad de Córdoba, Colombia

model or Oswald de Waele model the most notable Eq. (1):

$$\sigma = k\dot{\gamma}^n \quad (1)$$

where,

$\sigma$ = The shear stress
$k$ = The consistency index
$\dot{\gamma}$ = The shear rate
$n$ = The flow behavior index

Nowadays, in the available scientific literature, there is no information about the rheological parameters of sapote pulp added with MD and GA, therefore, the aim of this research was to evaluate the effect of maltodextrin and gum arabic concentration (15, 20, 25 and 30%, respectively (w/w)) on the rheological behavior of the sapote pulp (C*alocarpum sapota* Merr).

## MATERIALS AND METHODS

**Preparation of sapote pulp:** Sapotes used in this study came from the municipalities of Valencia and Tierralta in Colombia. Fruits were thoroughly washed, blanched at 75°C for 5 min in water with added citric-acid at 1% (w/w) to avoid some browning reactions. Then, the fruits were chilled at ambient temperature at 25°C, pulped and refined. The extracted pulp was packed and stored at a freezing temperature of -10±1°C.

Chemical analyses performed on the sapote pulp were: pH, through a Seven Easy S20 Metler Toledo potentiometer; vitamin C concentration, through a UV *vis* 1800 *Shimatsu* spectrophotometer; and soluble solids, through a Quick Brix 60 Mettler Toledo refractometer.

**Determination of rheological parameters:** Experiments were conducted at 25°C under a completely random design with a 2×4 factorial arrangement for the factors: encapsulant concentration (15, 20, 25 and 30%, respectively (w/w)) and the type of encapsulant (GA and MD). Each experimental trial was performed with three repetitions and the response variables were consistency index and flow behavior index. Variance analyses ($p \leq 0.05$) on main effects were performed to determine the influence of the aforementioned factors over the response variables.

To determine rheological parameters, sapote samples were prepared with the MA or GA concentrations. Experimental trials of continuous flow ramp were made in both ascending and descending ways through an AR 1500ex Rheometer, varying shear rate between 0.5 a 100/sec, with a waiting time of 10 sec when the maximum rate was reached.

The power law model was adjusted to the experimental data, using EXCEL'S® Solver tool, furthermore, the thixotropy percentage was determined through the measurement of the region area between ascending and descending curves of the shear stress against shear rate.

Table 1: Physicochemical characterization of sapote pulp

| Physicochemical parameters | Value |
|---|---|
| pH | 5.80±0.10 |
| Vitamin C (mg/100 g) | 20.80±0.13 |
| Soluble solids (°Brix) | 18.70±0.31 |

Table 2: Rheological parameters of the power law of sapote pulp

| | | Maltodextrin | | |
|---|---|---|---|---|
| Encapsulant concentration | | n | k (Pa.s$^n$) | $R^2$ |
| 0% | Ascent | 0.2747 | 68.089 | 0.987 |
| | Descent | 0.2798 | 51.068 | 0.968 |
| 15% | Ascent | 0.1563 | 110.205 | 0.999 |
| | Descent | 0.1672 | 91.547 | 0.989 |
| 20% | Ascent | 0.1097 | 119.120 | 0.994 |
| | Descent | 0.1195 | 100.075 | 0.971 |
| 25% | Ascent | 0.0602 | 136.922 | 0.996 |
| | Descent | 0.0705 | 118.268 | 0.980 |
| 30% | Ascent | 0.0359 | 189.768 | 0.994 |
| | Descent | 0.0429 | 166.170 | 0.970 |
| | | Gum arabic | | |
| 0% | Ascent | 0.2747 | 68.089 | 0.987 |
| | Descent | 0.2798 | 51.068 | 0.968 |
| 15% | Ascent | 0.2582 | 140.636 | 0.994 |
| | Descent | 0.2653 | 108.524 | 0.970 |
| 20% | Ascent | 0.1817 | 160.867 | 0.997 |
| | Descent | 0.1995 | 120.950 | 0.977 |
| 25% | Ascent | 0.1490 | 195.694 | 0.999 |
| | Descent | 0.1530 | 166.415 | 0.989 |
| 30% | Ascent | 0.1046 | 289.759 | 0.999 |
| | Descent | 0.1176 | 238.288 | 0.979 |

$R^2$: Coefficient of determination

## RESULTS AND DISCUSSION

Table 1 shows the obtained values of the physicochemical characterization of sapote pulp. The obtained value for soluble solids confirms that sapote possesses high contents of soluble solids. Villalva *et al*. (2006) and Simanca *et al*. (2002) report similar values, even though those values were slightly above the current work due to the different ripening stages of the fruits used in the study or the season in which they were collected.

On the other hand, the obtained values for vitamin C show sapote as a rich-vitamin C fruit and such values are consistent with those reported by the Colombian Family Welfare Institute (CFWI, 2015) which shows its antioxidant properties.

Finally, the pH value is similar to that reported by Simanca *et al*. (2002) showing values close to neutrality and low-acid content.

**Determination of rheological parameters:** The rheological behavior of sapote pulp under different maltodextrin and gum Arabic concentrations were predicted accurately through the Ostwald de Waele's model or power law (with $R^2 \geq 0.9914$). Sapote pulp showed non-Newtonian pseudoplastic behavior given the fact that values for the flow behavior index ($n$) were lower than one as shown in Table 2. These results are consistent with those reported by Andrade *et al*. (2010) for the sapote variety used in this study. A big amount of fruit pulps show similar behavior as the one

Table 3: Percent of thixotropy (%) of the sapote pulp

| Thixotropy (%) | | |
|---|---|---|
| Concentration (%) | Maltodextrin | Gum arabic |
| 0 | 23.5 | 23.5 |
| 15 | 13.4 | 20.7 |
| 20 | 12.8 | 19.5 |
| 25 | 10.2 | 14.2 |
| 30 | 10.1 | 13.6 |

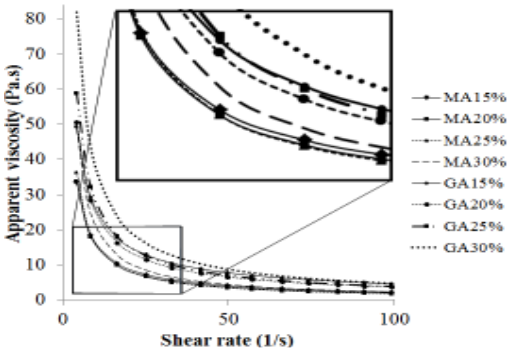


Fig. 1: Rheogram of sapote pulp with different concentrations of Maltodextrin (MA) and Gum Arabic (GA)

presented by guava and sapodilla (Andrade *et al*., 2009a, 2009b), mango (Vidal *et al*., 2004; Dak *et al*., 2007), among others. Keeping in mind the $n$ values, sapote pulp gains pseudoplasticity as the maltodextrin and gum arabic concentrations increase.

The variance analysis for $n$ and for $k$ showed the existence of significant differences in both parameters between the different encapsulants concentration as well as for the type of encapsulants.

In industrial terms, this pseudoplastic behavior guarantees lower energy consumption in flow processes because the apparent viscosity reduction causes lower pressure drop (Andrade *et al*., 2010).

The $n$ and $k$ values of the ascending and descending curves for each maltodextrin and gum arabic concentration showed hysteresis, marking thixotropy within the range of concentrations of the studied encapsulants. The values of the aforementioned thixotropy percentages are shown in Table 3. This behavior is consistent with that of some guava pulp varieties (Klom Sali hybrid, Puerto Rico, D14 y Red) as reported by Andrade *et al*. (2009a).

Figure 1 shows the rheological behavior of sapote pulp in which the apparent viscosity reduction is evident as the shear rate is increased and thus confirming the pseudoplastic behavior of sapote pulp.

It was also observed that sapote pulp without encapsulant shows lower viscosity than when the encapsulant is added because of the lower soluble solids concentration.

## CONCLUSION

Sapote pulp, under different concentrations of added maltodextrin or gum arabic, showed non-Newtonian with pseudoplastic nature and time-dependent rheological behavior. The greater the concentration of maltodextrin or gum arabic, the more pseudoplastic the pulp becomes.

The apparent viscosity of the pulp shows greater values with the addition of gum arabic than with that of maltodextrin when subjected to the same shear stress values.

Oswald de Waele's model or power law was properly adjusted with the experimental data for shear rate and shear stress of sapote pulp.

Pulp without encapsulant showed a greater thixotropy percentage which decreases as the concentration of encapsulant is increased; although it is worth mentioning that gum arabic shows greater thixotropic behavior than with maltodextrin in the same concentrations.

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## CONFLICT OF INTEREST

The manuscript was prepared and reviewed with the participation of all authors, who declare that there is no conflict of interests in the present study.

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