Use of waste from the processing of Sanky pulp (*Corryocactus brevistylus*) to obtain a food additive.

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Abstract- The objective of the research was to develop a process to obtain powdered mucilage from waste or residues generated after the mechanical separation of juice or pulp from the Sanky fruit. The residue was exposed to an aqueous-alkaline extraction process, evaluating the effect of time, temperature and pH on the viscosity of the extract obtained. Subsequently, the viscous extract was dryed by atomization, using 5-10% w/v maltodextrin DE10 as encapsulant; which allowed obtaining a powder additive with rheological properties similar to gum arabic, commonly used as a stabilizer and processing aid in the food and pharmaceutical industry.

Keywords - Corryocactus brevistylus, Sanky, natural additives, rheological properties, food additive.

I. INTRODUCTION

Sanky (*Corryocactus brevistylus*) or Socconporo in Quechua, is a plant that grows in the heights of the Peruvian highlands whose crops are still wild in Ayacucho and Huancavelica (2,658 m.a.s.l).

A decade ago, the use of Sanky was limited due to difficulties in post-harvest management and lack of knowledge of its food potential, so consumption is being minimal and only as a fresh fruit in the regions where grows [1]. However, nowadays it is considered a promising fruit, having economic importance for the inhabitants of the southern highlands of Peru mainly Huancavelica. The fruit provides a pulp valuable for its nutritional and functional properties that may be added in food development, thus its commercial exploitation is increasing considerably.

The pulp has low sugar content and has a slightly acid taste, its potassium content is higher than fruit such as bananas up to 40%; also it has 43.40 mg of vitamin C/100 g of pulp, and a large antioxidant capacity quantified in 474.8 ug eq.Trolox/g [2][3]. Due to some of these properties, Sanky pulp has been included in development of functional beverages either individually or accompanied with pulps from other tropical fruits such as passion fruit or pineapple [4][5][6]. The substitution of sucrose in beverage formulation has been evaluated by using stevia and/or sucralose [5][6]. The results of these initiatives end up being valuable for the mass consumption of the fruit and its derivatives.

Sanky´s pulp yield is greater than 50%; its shrinkage obtained are husks rich in fiber and seeds that are joint to extremely viscous mucilage. The yield of seed separation ranges from 10 to 25% [2][3], and is depending on state of maturity and overexposure to the mechanical agitation of the pulp by directly influencing the viscosity, therefore this increase the adherence of pulp to the seed and, consequently, increasing the waste during processing [4].

This phenomenon is mainly due to mucilage of Sanky seed, which in particular is a soluble fiber in aqueous medium slightly acidic and by agitation, tends to increase its volume considerably and maintains a moisture layer around the seed granting a waste with viscous nature.

This research is focus on using the waste generated by mechanically separating the seeds from the pulp of the fruit, commonly called cake, to obtain a biopolymer of a viscous nature to be used as an additive in food or pharmaceutical processes.

II. MATERIALS & MÉTHODS

A. *Processing of Sanky: Waste obtention*

Sanky (*Corryocactus brevistylus*), was obtained by recollection in field over 2650 meters above sea level (m.a.s.l) in Huaytara district (Huancavelica, Perú), between June-October. Processing of recollected fruit was carried out in an agroindutrial plant using equipment at pilot scale following the operations detailed in Fig. 1. From operation of pulping, the viscous nature cake (waste) was obtained and this was used as a raw material aiming to produce the additive.

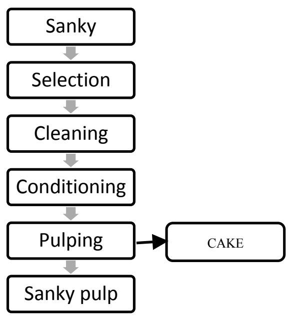

Fig. 1 Processing of Sanky (*Corryocactus brevistylus*) fruit.

B. *Design of the extraction process and stabilization of the additive obtained by using the waste (cake).*

Once the cake is obtained as a waste, the followed operation in Fig. 2. were carried out. To set best mucilage extraction conditions from Sanky waste, a complete factorial design 2^3 (Table I) was experimented having as variables pH (8-10), temperatura (60-80 ° C) and time (1-2 hours) as experimentation levels.

Digital Object Identifier (DOI): http://dx.doi.org/10.18687/LACCEI2018.1.1.412
ISBN: 978-0-9993443-1-6
ISSN: 2414-6390

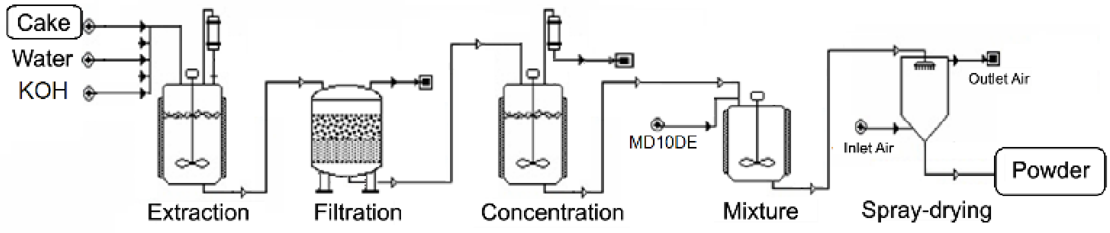

Fig. 2 Flow diagram of the processing to manufacture food additive by the use of Sanky waste (cake).

The outcome was the maximum viscosity of the obtained extract (maximum cP). Aiming to determine viscosity of samples, was used a Viscotester iQ HAAKE ThermoFischer (Germany) with a concentric cylinder spindle and Peltier to control the temperature (20°C). Viscosity tests were carried out at a shear rate of 0 – 1936 for 5 minutes, and having as a result behavioural graphics of Aparent Viscosity vs. Shear Rate, determining the maximum viscosity for each test.

TABLE I
EXPERIMENTAL DESIGN DECODED FOR EXTRACTION PROCESS OF MUCILAGE FROM SANKY WASTE (CAKE)

Treatment	pH	Temperature (°C)	Time (hours)
1	10	60	1
2	8	60	1
3	10	80	2
4	10	80	1
5	8	60	2
6	8	80	2
7	8	80	1
8	10	60	2

Spray-drying of extracted mucilage from the optimum conditions essayed was carried out by a spray-dryer with a pressure nozzle at pilot scale. Operation parameters considered were inlet temperature of 130 ± 2 °C, feed flow 0.98 ± 0.02 Liters/hour, encapsulant proportion (maltodextrin DE10) de 5 y 10 % W/W. Yield (y) of dried powders were obtained according to Eq.(1).

$$y = \frac{W_2(1-X_{bh2})}{W_1(1-X_{bh1})} \ldots \text{(Eq. 1)}$$

Where W_1 is the weight of mucilage extract in grams (g), X_{bh1} is the moisture content of the extract expresed on wet basis, W_2 is the weight of spray-dried powder obtained in grams (g), and X_{bh2} is the moisture content of spray-dried powder expressed on wet basis.

C. Characterization of the obtained additive.

Characterization of the powder consisted in carrying out physical, chemical and rheological essays. Physico-chemical tests included hygroscopicity, solubility, humidity and water activity. Hygroscopicity was obtained following the procedure proposed by Ref. [12], thus 1- 2g of the obtained powder additive was weighed in a previously weighed capsule; then it was placed in a container with a tight lid containing a saturated solution of Na_2SO_4 (81% RH), and incubated at 25 °C. After 7 days, the capsule was weighed and the hygroscopic humidity was determined, units were expressed as g of moisture per 100 g of dry solids (g/100 g). To determine the solubility, the method proposed by Ref [9] was used as follows. A 2% w/v suspension of the powder additive (5 and 10% MD) was prepared, which was constantly agitated on a VELP Scientifica magnetic stirrer (ARE, Italy). Approximately 5 mL of the suspension was weighed in a previously weighed Petri dish and placed at 102 °C in a Memmert stove (UN30, Germany) for 24 hours. The weight difference was expressed as total solids (ST). On the other hand, an aliquot of the suspension was centrifuged at 5000 rpm for 30 min and the supernatant will be removed. Approximately 5 mL of the supernatant was weighed in a previously weighed Petri dish and placed at 102 ° C in a Memmert oven (UN30, Germany) for 24 hours. The weight difference was expressed as soluble solids (SS). The solubility (SD) or mass fraction of soluble solids with respect to the total ones was calculated according to the following Eq. (3):

$$SD = SS/ST \ldots \text{(Eq.3)}$$

To determine the Water Activity, we used Novasina water activity analyzer (LabSwift-aw, Spain). The indirect gravimetric method by drying was used in order to obtain moisture content [8] using a Memmert stove (UN30, Germany) at a temperature of 135 ° C for 2 hours.

The rheological tests performed on the obtained powder additive were carried out at suspensions of 0.5-2% w/v, and were compared with the rheological behavior of commercial gums (0.5-2% w / v of gum arabic and 0.1% w / v of guar gum). Analysis were performed using a Viscotester iQ HAAKE ThermoFischer (Germany), at a temperature of 20 °C at a shear rate of 0 - 1936 Hz for 5 minutes, obtaining the behavior graphs: Viscosity apparent vs. Shear rate. Power-Ostwald model was used to model data.

III. RESULTS & DISCUSSIONS

3.1 Sanky processing: obtaining waste

Table II shows average yields of pulp separation, seed and skin in some investigations performed on pulp. The pulp yield obtained in the study (50.9 ± 14.7) has similar values to those reported by Ref [3] and Ref. [4].

The yield differences on reports of seed separation from the pulp among different authors (Table II) may be due to factors such as

TABLE II
CHARACTERIZATION OF SANKY FRUIT PROCESSING

Component	Evangelista & Rivas, 2015	Málaga & Rodríguez, 2014	Nolazco & Guevara, 2007	In the study X ± D.S
Pulp	35.92	53.64	57.7	50.9 ± 14.7
Peel (Skin)	40.67	35.42	35.2	25.4 ± 5.0
Seed (cake)	23.41	10.90	7.1	23.7 ± 3.4

state of maturity, extraction technique, among others. During the processing of the Sanky, 23.7% of cake was obtained. These were composed of a mixture of pulp and seeds; which as a whole presented a viscous appearance; results may differ from those obtained by Ref [3] and Ref [4], because of the fact that former mentioned authors suspend or dilute the whole pulp in water prior to pulping (mechanical separation). In this way, separation of the seeds from the pulp is facilitated and the recovery of the pulp destined to the elaboration of nectars improves considerably. On the other hand, cake yields, are similar to those reported by Ref. [5] because the mechanical separation of the seeds was done directly using a pulper with similar technical characteristics as used in the present study, which significantly increases the viscosity of the pulp and generates a greater amount of shrinkage or cake during the operation.

3.2. Extraction and stabilization of the additive obtained from the waste.

Fig. 3 shows the graph of the rheological behavior of the aqueous extracts obtained according to the experimental design of Table 1, obtaining the maximum viscosity of each treatment for the statistical analysis.

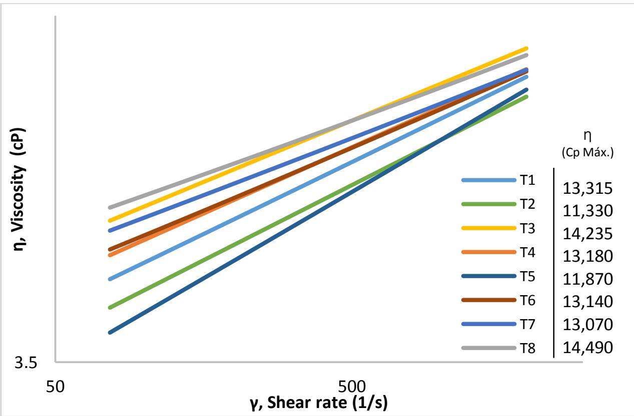

Fig. 3. The rheology of the mucilage extracted from Sanky's cake, at different conditions.

Fig. 4 shows statistical results of the experimental design. The effects countour plot of the study factors versus viscosity were obtained using the Minitab® software17.

The optimum conditions for each variable in Sanky mucilage extraction process were extraction temperature of 60 °C, extraction time of 2 h and pH of 10. Applying optimal extraction conditions of Sanky mucilage resulted a yield of 3.74% on dry basis. This result is higher value than those reported by Ref [10] and Ref. [11] who obtained 2.56% and 1.96% respectively during the aqueous extraction and alcohol precipitation of the cactus mucilage.

During the spray-drying of extracted mucilage at optimal conditions, a yield of 23.91% and 25.10% DB was obtained when using maltodextrin at 5 and 10% as encapsulating agent.

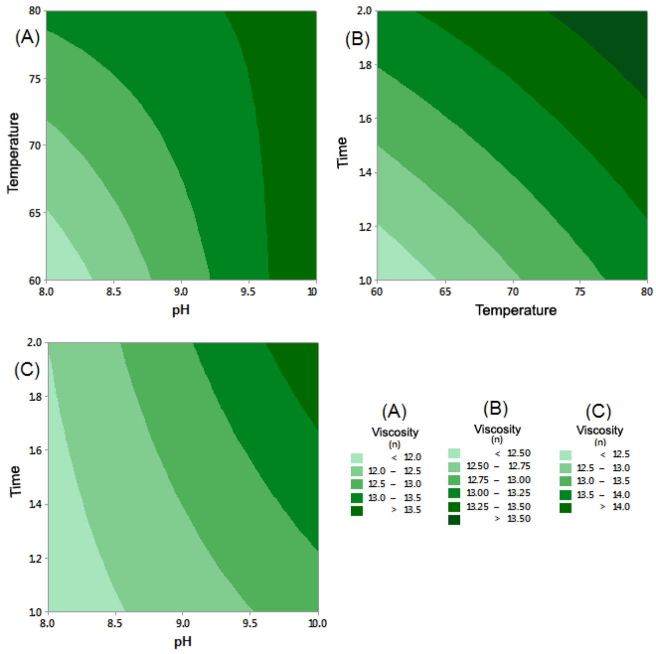

Fig. 4 Contour plot of the study variables according to the maximum viscosity of the aqueous extract.

3.3. Physical, chemical and rheological characterization of the obtained additive

In Table III, results of the physicochemical evaluation practiced on the spray-dried mucilage of Sanky at 2 encapsulation conditions at 5 and 10% of Maltodextrin DE10 are shown.

TABLA III
PHYSICOCHEMICAL CHARACTERISTICS OF SANKY SPRAY-DRIED MUCILAGE

Property	5 % MD	10 % MD
Hygroscopicity (g water/g DM)	0.92	0.73
Solubility (%)	95.57	98.02
Moisture (%)	5.98	4.55
Water activity	0.414	0.287

In Figure 5, the rheological behavior of Sanky spray-dried mucilages encapsulated at 5 and 10% WB of Maltodextrin DE10 considering suspensions at 0.5, 1 and 2% w/v are shown. Finally, Fig. 6 shows the rheological behavior of two commercial gums: gum arabic at 0.5-2% w/v and guar gum at 0.1% w/v, and its comparison with the obtained additive, where sanky mucilage with 10% MD on a 2% suspension has the same rheological behaviour as gum arabic in same conditions of suspension. Hence, Sanky mucilage is an important source of biopolymer, which can be used as a thickener in food industry.

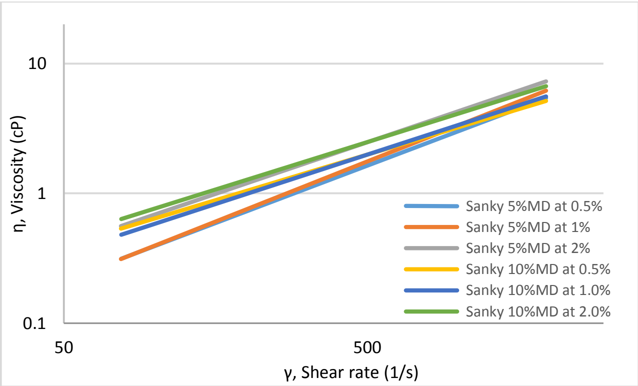

Fig. 5 Rheological behavior of Sanky spray-dried mucilage encapsulated with Maltodextrin.

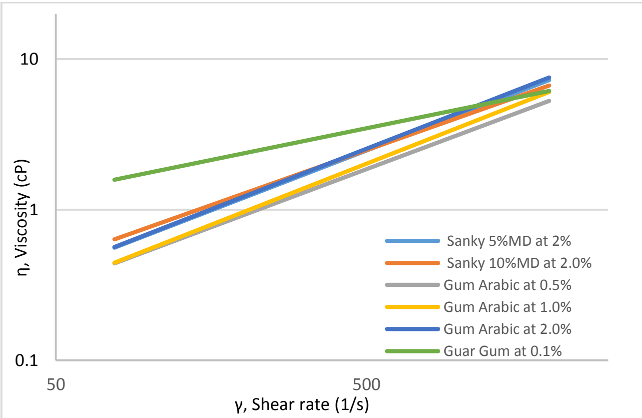

Fig. 6 Rheological behavior of Sanky spray-dried mucilage vs other commercial gums

IV. Conclusions

Under tested conditions during the aqueous-alkaline extraction process of the Sanky mucilage; pH 10, temperature 60 °C and 2 hours resulted as optimized parameters. During the spray-drying of Sanky's mucilage, the use of encapsulant at 5 and 10% Maltodextrin 10 DE did not significantly affect the yields of the process.

Rheological behavior of powdered mucilage obtained from the Sanky cake presented similar results to that of gum arabic in suspensions at 2% w/v; what makes possible its use of this as a possible food additive.

ACKNOWLEDGEMENT

The authors thank the Vice-Rector for Research of the Pontifical Catholic University of Peru for the financing of Project N ° 524, CAP 2015-PUCP.

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