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Correlating physical and sensory texture measurements of hearts of palm in conserve

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Abstract

A study correlating the physical and sensory texture measurements of hearts of palm in conserve was carried out with a view to establishing an instrumental texture standard for this product. One hundred hearts of palm sticks in conserve from different brands, 50 of Açaí and 50 of Pupunha, were cut in half cross wise. One of the halves was used for the sensory evaluation and the other for the instrumental evaluation. Fifty consumers were instructed to bite each half-stick received in the crosswise direction and evaluate the hardness on a linear 10 cm scale and the acceptability of the hardness on a nine-point hedonic scale. The instrumental hardness was analyzed using the TA-XT2 texturometer. The Pearson correlation between the force required to cut the hearts of palm sticks and the acceptability of the hardness was negative and significant at $p < 0.05$, that is, the greater the force required to cut the stick, the less the consumer liked it. Considering that the maximum acceptable sensory hardness is 5.0 on the 10 cm scale, the maximum acceptable values for the physical measurements are: maximum force/area: 20.4 N/cm^2 and mean force/area: 5.6 N/cm^2.

Keywords: hearts of palm; texture; sensory analysis; correlation.

Practical Application: The numerical standard texture can be used as a technical subsidy to complement the Brazilian legislation on canned hearts of palm industrialization process, as well as for the evaluation of the product, since texture is its main quality attribute.

1 Introduction

According to Resolution RDC nº17 of November 19th 1999, hearts of palm in conserve is the product prepared from the edible part of healthy palms of species adequate for human consumption, which have been removed from the fibrous parts by peeling and cutting, immersed in water with added herbs and other ingredients, processed (acidification and heat pasteurization) in an appropriate manner to guarantee a product free from viable forms of microorganisms capable of reproducing in the food under normal storage conditions, distribution and commercialization, and hermetically sealed to avoid the entrance of microorganisms and guarantee product sterility (Brasil, 1999).

Of the palms that can be used in the production of hearts of palm, the following stand out: juçara (*Euterpe edulis Martius*), açai (*Euterpe oleraceae Martius*), pupunha (*Bactrisgasipaes Kunth*) and various species of Royal Australian palms, the most common being *Archontophoenix alexandrae* and *Archontophoenix cunninghamiana* (Resende et al., 2009).

According to Rodrigues (2011), based on IBGE (Brazilian Institute of Geography and Statistics) data for the same year, the area planted with palms suitable for hearts of palm in Brazil increased from 1.5 thousand hectares in 1996 to 16.2 thousand hectares in 2009. In this same period the production by permanent farmers increased from 1.5 thousand tons to 70.8 thousand tons, whilst extractive production fell from 18.1 thousand tons to a very small value of 5.0 thousand tons.

The Amazon delta in the states of Amapá and Pará is the most important hearts of palm producing region in Brazil. In the southeast the activity has increased significantly in the State of São Paulo, which has an area of 5,200 hectares planted with pupunha palms, of which 4000 hectares are located in the Ribeira valley. Between 2007 and 2011, the number of medium and large sized industries increased from 6 to 10 in the state of São Paulo.

Based on the 2011 data of SECEX (Secretariat for Foreign Commerce of the Ministry of Development, Industry and Foreign Commerce in Brazil), Rodrigues (2011) showed that of the total amount of hearts of palm produced (on farms and by extractive production) in 2009, only 1,634 tons were exported, showing a tendency to decrease since 1993, year in which 11,389 tons were exported.

Although the acceptance of hearts of palm on the world market has increased little in recent years, even though the processed vegetable segment has presented a favorable tendency for growth, in Brazil its potential for use and acceptance in the national cuisine has increased. It is a widely used ingredient in the preparation of pizzas, salads, pastries and tarts, amongst other dishes. This tendency, associated with the search for natural, exotic and low calorie foods may still give an impulse to the world market for hearts of palm in coming years (Resende et al., 2009).

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Amongst the essential quality factors established for hearts of palm in conserve by Resolution RDC nº 17 of November 19th 1999 (Brasil, 1999), the following sensory attributes can be found: a) characteristic aspect of the stalk, with the absence of defects such as knife marks, scratches, broken and/or small bits, bunches of embryos; b) color, which should be characteristic, varying from white to slightly pinkish, cream, grey or yellowish; c) characteristic flavor and d) characteristic texture, that is, cut with the slightest of pressure without breaking up, being free of tough fibers which impede cutting and make swallowing difficult. The authors Berbari et al. (2008), who evaluated the quality of the hearts of palm from the Royal Australian palms (*Archontophoenixalexandrae* and *Archontophoenixcunninghamiana*) as compared to the hearts of palm obtained from the palms Açai (*Euterpe oleracea*) and Pupunha (*Bactrisgasipaes*), considered texture to be the most important parameter for this product.

Texture is the quality determining characteristic of many foods, even more important than flavor, and can be measured by both sensory and physical methods. According to Brown et al. (1996) and Rosenthal (1999), no equipment is capable of simulating the sensory evaluation of texture with exactness, since the perception of texture is complex and involves various attributes at the same time. However, according to Green et al. (1985), instrumental methods are quicker, easily applied and standardized, allow for greater reproducibility and require a smaller number of trained individuals for the analyses. Nevertheless, according to Szczesniak (1987), who developed the Texture Profile Methodology, the principals of which were employed in the conception of the texturometer, the definition of the physical method to be employed in a texture analysis should always be based on sensory perception, since only the human senses can perceive, describe and quantify the texture in a complete way. In the opinion of Wilkinson et al. (2000), the need for quality control equipment allied to the interest in knowing the consumer response and to understand which attributes are perceived during the evaluation of texture, are the main factors motivating research on correlations between physical and sensory responses.

Since texture is the main quality factor for hearts of palm in conserve and there are no studies showing how this characteristic influences consumer perception concerning product quality, this work aimed to study the correlation between the physical and sensory measurements of the texture of hearts of palm in conserve, with a view to establishing a limiting value up to which the quality, in the perception of the consumer, was not prejudiced. Thus the Technical Regulation, which fixes the standard of identity and quality to which hearts of palm in conserve should conform, could objectively contemplate the texture in the item "Essential quality factors", in the same way as it determines the maximum limit for pH value and the minimum limit for vacuum in the package, amongst other factors.

2 Material and methods

The pH value of the covering liquid in each pack was evaluated, since this is an essential quality factor, the maximum permitted limit being 4.50 according to Resolution RDC nº 17 of November 1999 (Brasil, 1999). None of the packs showed a pH value above 4.5.

One hundred hearts of palm sticks in conserve from different brands, 50 being Açaí and 50 Pupunha, were cut in half crosswise and one half evaluated sensorially and the other instrumentally. Excessively hard sticks, which were impossible to cut with a knife, were discarded since they could not be used in the sensory evaluation.

Fifty hearts of palm consumers were recruited for the sensory evaluation, aged between 18 and 60 and belonging to social classes A/B/C according to the Brazilian Economic Classification Standard Criterion of 2012 (Associação Brasileira de Empresas de Pesquisa, 2012). This criterion is a tool for economic targeting which takes into account some domestic appliances for comfort and the householder's level of schooling. The standard attributes scores based in each families trait and adds them. Then, the corresponding Standard range is matched to economic stratum ranging between A1, A2, B1, B2, C1, C2, D, and E, in decrescent order.

The judges were instructed to bite each half-stick received (Açaí and Pupunha) in a crosswise direction and evaluate the hardness on a linear 10 cm scale anchored at the extremes by the expressions: "extremely soft" and "extremely hard", and then evaluate the acceptability of the hardness on a nine-point hedonic scale (9 = liked extremely, 5 = neither liked nor disliked and 1 = disliked extremely) according to Meilgaard et al. (2006). The test was carried out in individual booths with fluorescent lighting and equipped with the *Compusense Five versão 4.8* data collection and analysis system. The consumers also replied to questions concerning their hearts of palm consumption habits and personal characteristics related to their age and definition of social class. This research project was evaluated by the ethics committee of the "Faculdade de Ciências Médicas"- Unicamp. The evaluation process is the No. 1226/2009.

Instrumental hardness (maximum force/area and mean force/area) was analyzed using the SMS TA-XT2 texturometer operating with the Texture Expert software and using the HDP/BS probe (reversible blade) in the force/compression mode, with pre-test and test speeds of 3.0 mm/s, a post-test speed of 10.0 mm/s and a distance of 40 mm.

Since the diameters of the sticks varied considerably, and consequently the cross-section cut during the physical analysis also varied, the results of these measurements had to be corrected. So, each half stick which was evaluated for its instrumental texture was measured with a caliper rule at the central region where, later, it was cut by the texturometer. The cross section area [$A = \pi(D/2)^2$] was computed to express Maximum and Mean Forces by one unity of area. The results obtained were correlated with the sensory attributes using the Pearson's linear correlation test.

3 Results and discussion

3.1 Characterization of the consumer group recruited for the test

Of the 50 consumers who took part in the test, 43 were women and 7 men. Figure 1 shows their characteristics with respect to age range, social class, frequency and type of hearts of palm consumed and the consumption mode.

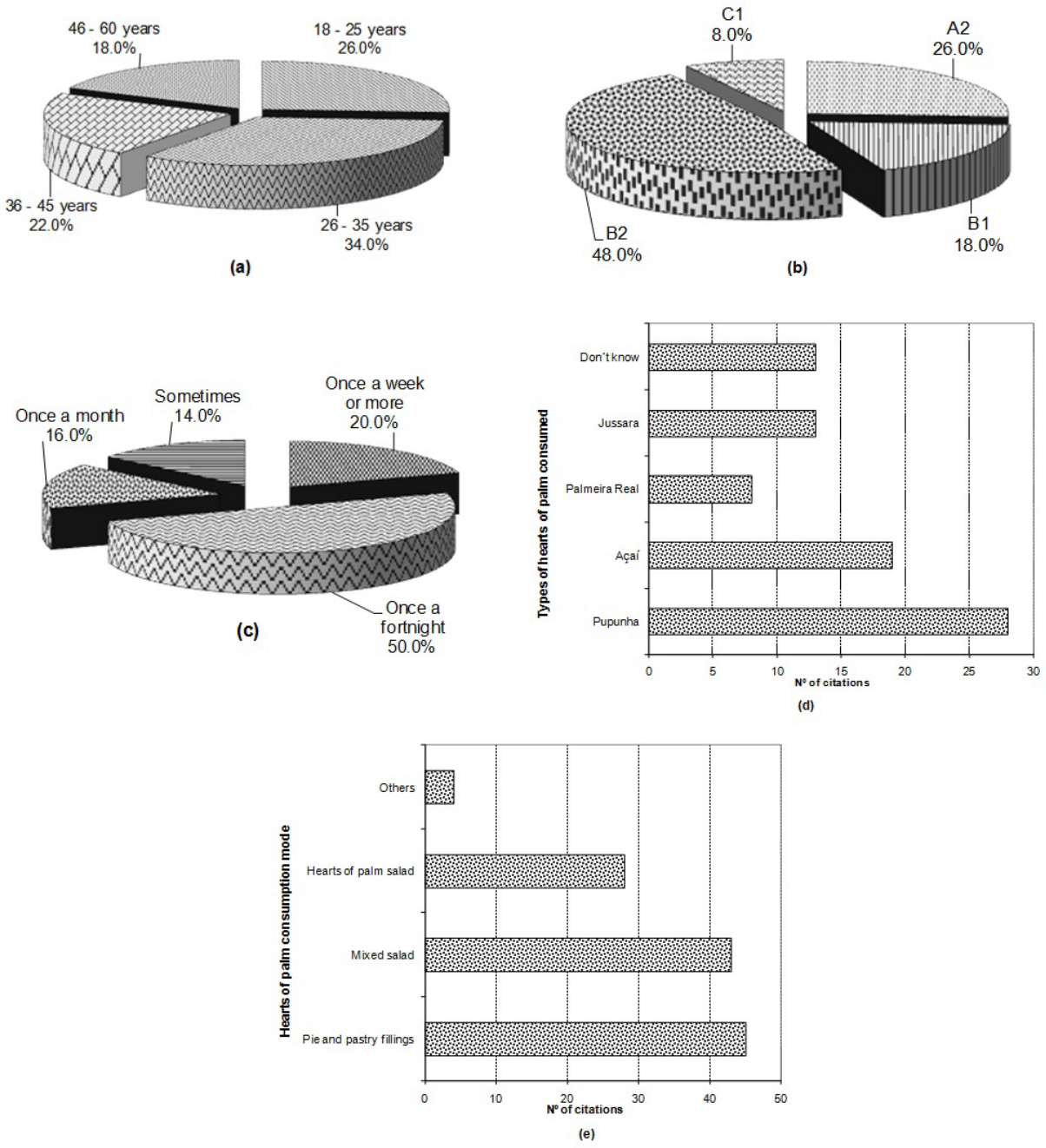

Figure 1. Age range (a), social class (b), frequency (c), types (d) and hearts of palm consumption mode (e) cited by the consumers recruited for the test.

3.2 Results of sensory test and instrumental texture evaluation

Table 1 shows the physical and sensory measurements, Table 2 shows the minimum, the maximum, the mean and standard deviation of the Açaí and Pupunha hearts of palm sticks evaluated. Table 3 shows the Pearson correlations between the variables: maximum force/area, mean force/area, sensory hardness and acceptability of the hardness of the Açaí and Pupunha hearts of palm.

Statistical analysis (ANOVA), aiming the comparison between the two varieties, showed that Pupunha presented higher diameter and, consequently, higher crosswise area than Açaí ($p < 0.05$). Açaí was significantly harder than Pupunha ($p < 0.001$), measured instrumentally and by sensory analysis, as well (Table 2). Both types of hearts of palm presented means for hardness corresponding to "liked" on the scale used in this evaluation ($p > 0.05$).

Berbari et al. (2008) also obtained results for instrumental texture allowing for the conclusion that the hearts of palm

Table 1. Physical and sensory measurements of the *Açaí* and *Pupunha* hearts of palm sticks.

Stick		Diameter (cm)	Area (cm²)	Max. Force (N)	Mean Force (N)	Max. force/Area (N/cm²)	Mean force/Area (N/cm²)	Sensory hardness	Acceptability hardness	Stick		Diameter (cm)	Area (cm²)	Max. Force (N)	Mean Force (N)	Max. force/Area (N/cm²)	Mean force/Area (N/cm²)	Sensory hardness	Acceptability hardness
	1	2.325	4.246	19.847	5.012	4.675	1.181	2.4	8		51	3.650	10.463	5.756	2.512	0.550	0.240	1.4	7
	2	3.110	7.596	18.183	7.129	2.394	0.938	2.0	7		52	3.190	7.992	5.628	2.210	0.704	0.277	1.0	8
	3	3.100	7.548	19.271	7.404	2.553	0.981	0.5	8		53	4.060	12.946	18.434	3.818	1.424	0.295	0.6	6
	4	1.970	3.048	25.981	5.037	8.524	1.653	2.0	7		54	3.560	9.954	10.526	3.480	1.057	0.350	0.5	8
	5	1.975	3.064	34.838	5.212	11.372	1.701	0.9	8		55	3.320	8.631	18.050	4.216	2.091	0.488	0.8	8
	6	1.890	2.806	21.520	5.571	7.671	1.986	1.6	9		56	2.820	6.246	8.791	3.115	1.408	0.499	1.5	8
	7	2.840	6.335	31.450	9.880	4.965	1.560	0.5	8		57	2.680	5.641	8.974	3.070	1.591	0.544	0.5	3
	8	2.135	3.580	28.221	7.661	7.883	2.140	2.5	8		58	3.250	8.270	11.925	4.699	1.442	0.568	0.5	9
	9	3.040	7.258	32.024	10.940	4.412	1.507	0.4	8		59	2.550	5.087	10.613	3.372	2.086	0.663	1.0	4
	10	2.920	6.697	37.101	10.666	5.540	1.593	0.5	9		60	3.170	7.868	13.521	5.361	1.719	0.681	1.0	6
	11	2.665	5.578	42.218	9.876	7.569	1.770	0.5	7		61	2.950	6.835	14.956	5.066	2.188	0.741	0.5	8
	12	2.855	6.402	30.599	10.921	4.780	1.706	2.3	8		62	2.750	5.918	15.403	4.387	2.603	0.741	0.6	8
	13	2.635	5.453	29.651	10.203	5.437	1.871	0.4	9		63	2.640	5.474	14.585	4.167	2.664	0.761	1.4	7
	14	2.320	4.227	25.573	9.191	6.049	2.174	0.1	9		64	2.240	3.923	9.301	3.009	2.371	0.767	0.4	9
	15	2.195	3.784	33.284	9.383	8.796	2.480	1.8	7		65	3.290	8.475	15.453	6.530	1.823	0.770	1.0	6
	16	2.125	3.547	29.739	9.457	8.385	2.667	1.8	8		66	1.970	3.048	8.321	2.405	2.730	0.789	0.5	1
	17	1.945	2.971	35.589	8.659	11.978	2.914	0.8	8		67	2.870	6.447	12.909	5.264	2.002	0.817	1.6	8
	18	2.110	3.497	44.079	10.349	12.606	2.960	3.2	7		68	2.540	5.067	14.658	4.227	2.893	0.834	1.5	8
	19	2.630	5.433	37.294	13.418	6.865	2.470	0.5	9		69	2.450	4.714	12.676	3.960	2.689	0.840	0.5	2
Açaí	20	2.870	6.469	41.103	15.288	6.354	2.363	0.9	8	Pupunha	70	2.970	6.928	13.047	5.983	1.883	0.864	2.4	7
	21	2.150	3.631	41.400	11.514	11.403	3.171	2.6	8		71	2.970	6.905	15.689	5.965	2.272	0.864	0.4	7
	22	2.145	3.614	31.877	11.488	8.821	3.179	2.7	8		72	2.960	6.881	14.644	5.989	2.128	0.870	0.5	5
	23	2.215	3.853	64.217	12.186	16.665	3.162	1.0	8		73	2.540	5.047	22.329	4.579	4.424	0.907	2.2	7
	24	2.735	5.875	59.001	15.357	10.043	2.614	3.6	6		74	4.050	12.883	27.443	11.940	2.130	0.927	0.9	8
	25	1.770	2.461	46.792	10.264	19.017	4.171	3.3	8		75	2.190	3.750	12.066	3.546	3.218	0.946	0.6	9
	26	3.090	7.499	55.204	18.654	7.361	2.488	3.0	7		76	2.320	4.227	13.674	4.069	3.235	0.963	0.5	6
	27	2.770	6.026	61.294	16.765	10.171	2.782	2.5	4		77	1.780	2.488	9.565	2.450	3.844	0.985	1.0	8
	28	2.340	4.301	46.964	14.375	10.920	3.343	1.6	8		78	2.360	4.374	14.712	4.347	3.363	0.994	0.6	8
	29	2.320	4.227	49.536	15.647	11.718	3.701	4.8	7		79	2.540	5.047	15.502	5.043	3.071	0.999	0.5	9
	30	2.050	3.301	60.640	14.446	18.372	4.377	3.0	9		80	2.940	6.766	15.378	6.818	2.273	1.008	2.5	8
	31	2.470	4.792	60.721	17.889	12.672	3.733	4.0	7		81	2.070	3.349	15.933	3.394	4.757	1.013	0.9	9
	32	2.870	6.469	62.686	22.268	9.690	3.442	5.0	6		82	3.040	7.234	17.854	7.510	2.468	1.038	2.0	7
	33	3.260	8.347	73.250	25.566	8.776	3.063	5.0	6		83	2.040	3.269	15.587	3.405	4.769	1.042	1.1	9
	34	2.910	6.651	96.306	22.906	14.480	3.444	4.0	7		84	2.630	5.412	20.147	5.740	3.723	1.061	1.1	8
	35	2.970	6.928	83.217	23.669	12.012	3.416	4.3	6		85	2.440	4.676	17.907	5.145	3.830	1.100	1.1	9
	36	2.585	5.248	77.037	22.899	14.679	4.363	5.4	6		86	2.680	5.641	18.397	6.484	3.261	1.149	0.5	7
	37	2.495	4.889	63.720	23.016	13.033	4.708	5.0	7		87	2.570	5.167	22.229	6.715	4.302	1.300	1.8	7
	38	2.170	3.698	104.968	20.532	28.382	5.552	7.2	5		88	3.450	9.348	30.431	12.881	3.255	1.378	2.0	9
	39	2.330	4.264	63.158	22.473	14.812	5.271	5.0	4		89	2.890	6.560	40.480	10.558	6.171	1.610	3.6	7

Table 1. Continued...

Stick		Diameter (cm)	Area (cm^2)	Max. Force (N)	Mean Force (N)	Max. force/Area (N/cm^2)	Mean force/Area (N/cm^2)	Sensory hardness	Acceptability hardness	Stick		Diameter (cm)	Area (cm^2)	Max. Force (N)	Mean Force (N)	Max. force/Area (N/cm^2)	Mean force/Area (N/cm^2)	Sensory hardness	Acceptability hardness
	40	2.190	3.767	101.762	22.293	27.015	5.918	8.4	4		90	3.350	8.788	37.157	15.328	4.228	1.744	2.3	8
	41	2.300	4.155	81.767	23.935	19.680	5.761	5.4	7		91	3.020	7.139	39.159	13.959	5.485	1.955	2.8	7
	42	2.380	4.449	58.778	25.317	13.212	5.691	5.0	6		92	2.230	3.888	23.773	7.997	6.114	2.057	3.1	7
	43	2.725	5.832	86.118	30.369	14.766	5.207	5.9	6		93	3.270	8.373	44.538	19.807	5.320	2.366	5.3	7
	44	2.720	5.811	118.957	31.500	20.472	5.421	4.0	7		94	2.790	6.114	43.486	15.709	7.113	2.570	5.3	7
Açaí	45	3.220	8.143	138.720	37.377	17.035	4.590	5.0	6	Pupunha	95	3.040	7.258	36.062	19.793	4.968	2.727	5.3	6
	46	1.950	2.986	53.793	23.188	18.012	7.764	9.3	7		96	2.470	4.772	42.484	13.633	8.902	2.857	4.9	7
	47	3.180	7.942	150.155	41.819	18.906	5.265	4.8	6		97	2.520	4.968	73.105	22.677	14.716	4.565	2.7	9
	48	2.580	5.228	104.334	34.272	19.957	6.556	4.9	6		98	2.440	4.676	83.022	24.135	17.755	5.162	4.4	7
	49	3.020	7.163	121.775	49.269	17.000	6.878	5.1	9		99	2.520	4.968	67.484	27.125	13.584	5.460	5.0	7
	50	2.355	4.356	115.302	42.879	26.471	9.844	5.1	6		100	2.800	6.158	236.429	53.974	38.397	8.766	5.4	4

Table 2. Minimum, Maximum, Mean and Standard Deviation of the *Açaí* and *Pupunha* hearts of palm sticks evaluated.

Results		Minimum value	Maximum value	Mean (standard deviation)
Diameter (cm)	Açaí	1.770	3.260	2.518 (0.407)[b]
	Pupunha	1.780	4.060	2.797 (0.495)[a]
Area (cm^2)	Açaí	2.461	8.347	5.109 (1.630)[b]
	Pupunha	2.488	12.946	6.321 (2.277)[a]
Max. Force (N)	Açaí	18.183	150.155	59.020 (33.075)[a]
	Pupunha	5.628	236.429	26.604 (34.625)[b]
Mean Force (N)	Açaí	5.012	49.269	17.708 (10.529)[a]
	Pupunha	2.210	53.974	8.631 (8.978)[b]
Max. force/Area (N/cm^2)	Açaí	2.394	28.382	12.087 (6.219)[a]
	Pupunha	0.550	38.397	4.620 (5.934)[b]
Mean force/Area (N/cm^2)	Açaí	0.938	9.844	3.550 (1.891)[a]
	Pupunha	0.240	8.766	1.458 (1.548)[b]
Sensory hardness	Açaí	0.1	9.3	3.2 (2.2)[a]
	Pupunha	0.4	5.4	1.8 (1.6)[b]
Acceptability hardness	Açaí	4	9	7.1 (1.3)[a]
	Pupunha	1	9	7.1 (1.8)[a]

For each parameter, means followed by the same letter do not differ statistically ($p < 0.05$).

Table 3. Pearson's correlation between the variables of maximum force/area, mean force/area, sensory hardness and acceptability of the hardness for the hearts of palm Açaí and Pupunha.

Variable	Maximum force/Area	Mean force/area	Sensory hardness	Acceptability of hardness
Maximum force/area	-	0.9300***	0.7354***	- 0.2380*
Mean force/area	-	-	0.8065***	- 0.2151*
Sensory hardness	-	-	-	- 0.3138*
Acceptability	-	-	-	-

*p<0.05; ***p < 0.0001.

Pupunha was softer than that of Açaí, and also softer than the Royal hearts of palm. In the evaluation of the acceptability of texture, the hearts of palm of the three varieties studied obtained means situated between "liked" and "liked a lot" on the scale used, indicating good acceptance of the product. No other studies were encountered concerning the texture of hearts of palm and their acceptance by consumers.

The Pearson's correlation coefficients between the variables maximum force/area and mean force/area with sensory hardness were 0.7354 and 0.8065 ($p < 0.0001$), respectively, showing that both the maximum force/area and the mean force/area are directly correlated with sensory hardness, that is, the greater the force necessary to cut the stick crosswise, the greater the perceived sensory hardness. To the contrary, the correlation between the force necessary to cut the stick (measured instrumentally or sensorially) and the acceptance of the hardness by the consumers was negative and significant at $p < 0.05$, that is, the greater force necessary to cut the stick, the less the consumer liked the product (Table 3). Cohen (1988) recommended that values from 0.10 to 0.29 can be considered as a weak correlation; from 0.30 to 0.49 as a moderate correlation and values from 0.50 to 1 can be considered as a strong correlation. Dancey & Reidy (2006) proposed a classification slightly different:

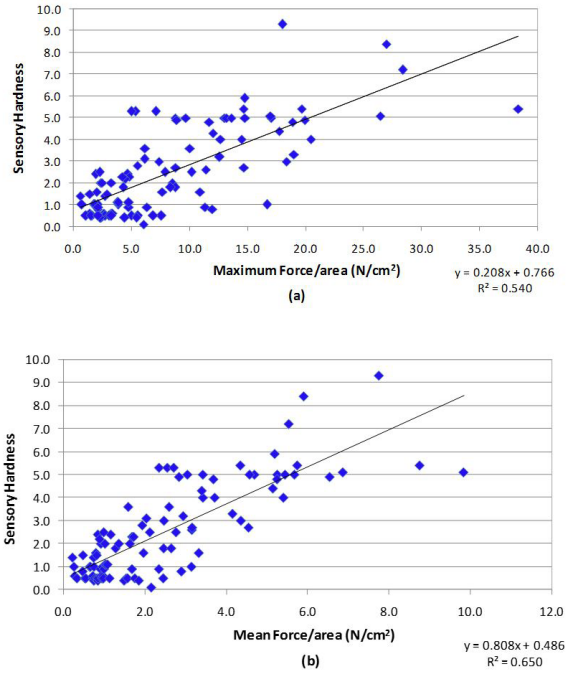

Figure 2. Correlation between maximum force/area (a) and mean force/area (b) with sensory hardness.

from 0.10 to 0.30: weak; from 0.40 to 0.60: moderate; from 0.70 to 1: strong. According to Evans (1996), less than 0.20, the correlation is very weak, from 0.20 to 0.39 is weak, 0.40 to 0.59 is moderate, 0.60 to 0.79 is strong and 0.80 or greater is a very strong correlation.

Figure 2a and 2b show, respectively, the graphs for the correlation between maximum force/area and mean force/area with sensory hardness, as also the respective equations for the curves obtained and the coefficients of determination (r^2), significant at $p < 0.0001$.

As from the curves, and considering that the maximum acceptable sensory hardness is 5.0 (central point of the scale used), one can determine the maximum acceptable values for the following physical measurements:

- Maximum force/area: 20.4 N/cm^2;
- Mean force/area: 5.6 N/cm^2.

4 Conclusions

This study allowed for the definition of a limiting value for the hardness of hearts of palm in conserve, up to which the product quality is acceptable. With this value, the texture can be considered in an objective way in the item "Essential quality factors" in the Technical Regulation that fixes the identity and quality standard for hearts of palm in conserve, since this is one of the most important parameters for the product in question.

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