OIL EXTRACTION FROM SHELL OF *Bactris gasipaes* HBK FRUITS USING COMPRESSED CARBON DIOXIDE

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ABSTRACT

This work deals with an integral study which is carried out at the present about the fruit of the *Bactris gasipaes* HBK palm tree known in the Peruvian Amazon as *pijuayo*, and it is proposed to extract its oil from the peel, pulp, and seed by using a pressurized carbon dioxide, by characterizing them from the point of view of its chemical composition to evaluate the kinetic process and by comparing with the results with those which were obtained through a conventional solid-liquid extraction of Soxhlet type—the hexane was used for such propose. The effect of the temperature such as the pressure, particle size, as well as the static period of the process was determined by using a Fractionate Factorial Design 2^{4-1}. The CO_2 high power solvate was taking in mind to evaluate pressures in their critic point by choosing a slightly superior pressure as well as another slightly inferior one at the point of 80 and 63 bar, and in order to determine the effects from those four studied variables, a variance analysis was done about the gotten results in each utilized experimental conditions.

It has been found that the temperature only develops a significant statistic effect in the process whether it can be in relation to the total extract quantity or to the saturated or unsaturated fatty acids, and the total oil quantity as well as about the quantity of the saturated fatty acids in the same augments with the temperature growth. However, the unsaturated quantity of fatty aids diminish in the same conditions, and due to it is evident that with the intention to get the best oil quality for food, it is recommended to work with the minor of those two evaluated temperatures (20°C and 27°C). It has been found also that 9,80% of the saturated fatty acids which are present in the obtained oil under the experimental conditions of 20°C, 80 bar without a period static and particle size of –8+10 mesh (experiment 3) secures an optimum food quality. Specially by comparing it with olive oil (saturated: 11,70%), colza oil (saturated: 7,30%) soy bean oil (saturated: 15,40%) and oil corn (saturated: 13,60 %)

Key words: Pijuayo; Bactris gasipaes; Guilielma gasipaes; Carbon dioxide; Pressurized Extraction; Oils

INTRODUCTION

The fruits of the palm Bactris gasipaes HBK "pijuayo" are drupes of different coloration: green, yellow, orange and red. They have diverse forms: conical, ovoid or ellipsoid and they are of different size, from very small (of 1,0 to 1,5 cm of diameter in fruits without seed), until very big (7 cm of diameter in normal fruits). It is distributed in the whole Amazonia and the tropical America. They are eatable in mature and cooked state: flour, pastures, canned in brine, canned in *cocona* sauce, etc. It is extracted eatable oil of the pulp fruit with unsaturated fatty acids of great demand in the current market. They possess a great nutritional wealth that is appreciated in the Table 1 [1].

Table 1: Nutritional content of 100 g of *pijuayo* pulp

Water	50,7%
Fat	5,8%
Proteins	6,3%
Carbohydrates	35,7%
Fiber	1,3%
Ash	0,8%
Calcium	14,0 mg
Phosphorus	16,0 mg
Iron	1,0 mg
Vitamin A	867,7 UI
Thiamin	0,05 mg
Riboflavin	0,16 mg
Niacin	1,4 mg
Ascorbic acid	3,5 mg
Calories	196

Except the *Mauritia flexuosa* "aguaje" and some preliminary researches with a type of *pijuayo*, few other amazon vegetable species of importance economic have been studied by means of the pressurized extraction technique [2,3].

I. - MATERIALS AND METHODS

Mature fruits of red *pijuayo* from the Experimental Center “El Dorado” of the INIA placed in the km 29 of the highway Iquitos-Nauta were used in this work. The fruits were separated in shell, pulp and seed. The average initial humidity of the shell was of 5,0% dehydrated to the environment. The equipment used is showed in the Figure 1 and it was described in a previous presentation [4]. The extraction with CO_2 pressurized it was carried out during 15 hours, using a average mass flow of 3,18 ± 0,06 $gmin^{-1}$, with a fractional factorial design 2^{4-1} of four variables and two levels, as one observes in the Table 1.

The fatty acids were esterificated according to the literature [5]. The identification of the fatty acids was carried out by gas chromatography with a Shimadzu CG 17A instrument equipped with a FID (flame ionization detector), and a 30 m (0,25 mm i.d.) fused silica VA-WAX capillary column. Helium was used as carrier gas with a flow of 1 $mLmin^{-1}$. The programming of column temperature was of 150ºC during 11 minutes, heating of 3ºC per minute up to 210ºC, remaining for 5 minutes to this temperature.

Table 1: Experimental design – Fractionated Factorial 2^{4-1}

Test	Pressure (bar)	Temperature (ºC)	Particle size (mesh)	Static Time (hours)
2	80	27	-10+14	0
4	80	20	-10+14	1
7	65	20	-8+10	1
3	80	20	-8+10	0
6	65	27	-10+14	1
8	65	20	-10+14	0
5	65	27	-8+10	0
1	80	27	-8+10	1

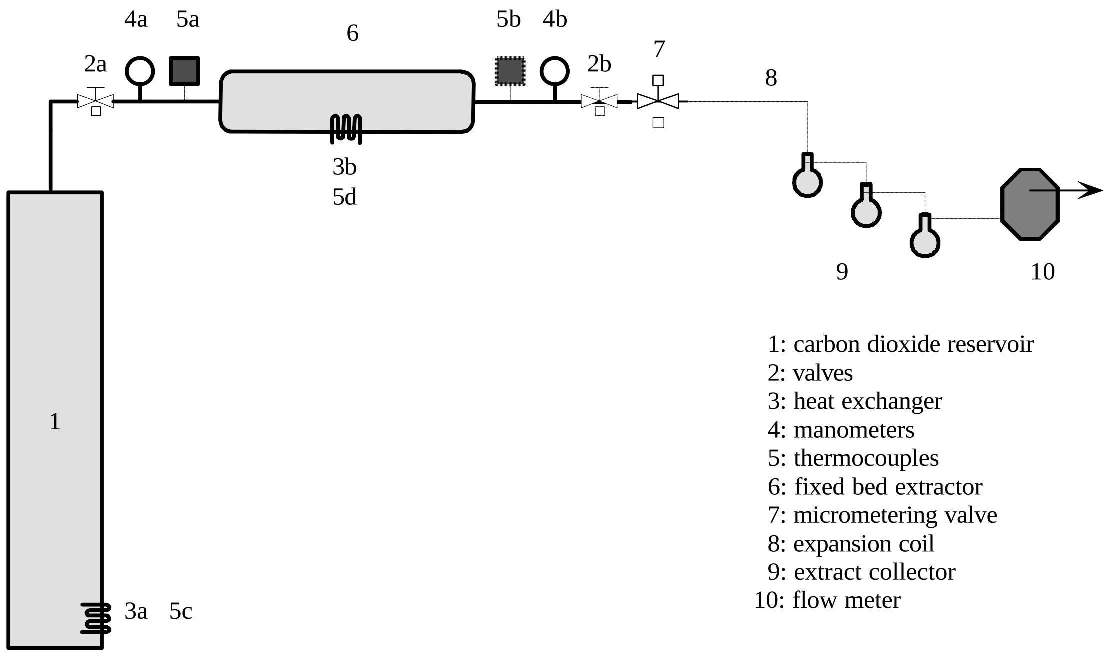

Figure 1: Diagram of the experimental unit of extraction with pressurized fluids

II. - RESULTS AND DISCUSSIONS

Using the Experimental Design module of the commercial software Statistica 6.0 it was carried out the ANOVA of the total extracts showed in the second column of the Table 2. It was observed that for an evaluation at 95% of significance level, there is statistically significant effect only of the temperature ($p = 0{,}0127$), because when increasing the temperature from 20,1 ± 0,7ºC to 27,0 ± 0,1ºC, the total yield of extract increases in 3,18 points average, independent of the other three variables.

Due to the importance of the poly-unsaturated fatty acids in the human physiology, it was carried out a similar ANOVA using the fifth column data of the Table 2, and it was observed again the existence of statistically significant effect only of the temperature (p = 0,0035), although much more notorious, and in inverse sense to the effect shown for the total extract, that is, when increasing the temperature from 20,1 ± 0,7ºC to 27,0 ± 0,1ºC, the total yield of poly-unsaturated fatty acids (linoleic and linolenic) diminishes in 4,27 points average, independent of the other three variables in study. The analysis of variances in function to the content of saturated fatty acids shows the effect once again statistically significant of the temperature (p = 0,0028) with a yield increase more than 23 points with the temperature.

Table 2: Yields of extract according to fatty acids class

Test	Extract Yield (%)	Percentual composition of fatty acid groups				
		Saturated	Mono-unsaturated	Poly-unsaturated		
				SubTotal	Linoleic	Linolenic
2	12,04	32,13	55,45	12,42	9,08	3,34
4	9,13	12,14	70,51	17,35	12,55	4,80
7	8,38	15,68	67,55	16,77	12,21	4,56
3	7,08	9,80	72,78	17,41	12,75	4,67
6	10,47	34,97	51,48	13,55	9,69	3,86
8	7,23	15,18	68,14	16,77	12,06	4,71
5	10,25	36,58	50,26	13,17	9,38	3,79
1	11,79	41,49	46,42	12,09	8,69	3,40
Average	9,55	24,75	62,32	15,02	10,80	4,15
Standard Deviation	1,91	12,74	10,48	2,28	1,74	0,60

All the above mentioned takes to conclude that working in the critical pint vicinity of the CO_2 (65 and 80 bar), and considering as oil quality index its minimization of saturated fatty acids and maximization of unsaturated fatty acids, it is preferable to work with smaller temperatures than critical temperature (around 20ºC), this is, guaranteeing the state of compressed liquid of the solvent, although these conditions don't guarantee the maximum total yield of oil.

The Table 3 shows the fatty acids composition in the oil of the *pijuayo* shell in function to the different experimental conditions of temperature, pressure, mesh and static times, and as it was already discussed in the precedent paragraphs, the first of these variables only exercises significant effect in the different results. It also shows in a comparative way their composition of fatty acids in relation to the oil of other important vegetable oleaginous species. It is observed that the biggest concentration corresponds to the unsaturated fatty acids, especially in the experiments 3, 4, 7 and 8. The two firsts, with temperatures of around 20ºC and pressures of around 80 bar present a composition of saturated and unsaturated fatty acids very similar to the oil of vegetable species of grateful alimentary quality as the olive oil, the colza oil, the soy oil and the corn oil. If the oil obtained in the experiment 3 (80 bar, 20ºC, -8+10 mesh and without static period) it is compared with the oil of the 4 before mentioned species, in function to the content of saturated fatty acids, it is observed that alone it loses for the colza oil.

Table 3: Fatty acids of *pijuayo* shell oil extracted with CO_2 and of oil of other vegetable species conventionally extracted

Fatty Acids	Tests								Other oils [6]			
	1	2	3	4	5	6	7	8	Olive	Colza	Soy	Corn
Saturated	41,49	32,13	9,80	12,14	36,58	34,97	15,68	15,18	11,70	7,30	15,40	13,60
C 12:0	0,10	-	0,13	0,12	0,12	0,12	0,11	0,13	-	-	-	-
C 14:0	0,18	0,11	0,21	0,20	0,21	0,21	0,20	0,20	-	0,10	0,10	0,10
C 15:0	0,27	0,19	0,20	0,21	0,29	0,29	0,24	0,22	-	-	-	-
C 16:0	38,07	28,35	8,16	10,21	33,96	32,27	13,41	13,36	9,00	3,80	10,60	10,90
C 17:0	0,17	0,21	-	0,11	0,16	0,15	0,13	-	-		0,10	0,10
C 18:0	1,99	2,34	0,94	1,10	1,47	1,48	1,22	1,06	2,70	1,20	4,00	2,00
C 20:0	0,41	0,56	0,16	0,20	0,27	0,27	0,25	0,20	0,40	0,70	0,30	0,40
C 22:0	0,16	0,21	-	-	0,10	0,10	0,12	-	-	0,50	0,30	0,10
C 24:0	0,14	0,16	-	-	-	0,08	-	-	-	1,00	-	-
Monounsaturated	46,42	55,45	72,78	70,51	50,26	51,48	67,55	68,14	86,30	66,50	23,30	25,60
C 16:1	4,24	3,83	7,01	7,11	6,11	6,23	7,15	6,95	0,60	0,30	0,10	0,20
C 17:1	0,10	0,16	0,18	0,16	0,12	0,12	0,15	0,15				
C 18:1	41,68	50,92	65,02	62,72	43,77	44,86	59,73	60,54	80,30	18,50	23,20	25,40
C 20:1	0,33	0,54	0,57	0,52	0,27	0,27	0,52	0,50	-	6,60	-	-
C 22:1	0,08	-	-	-	-	-	-	-	-	41,10	-	-
Poly-unsaturated	12,09	12,42	17,41	17,35	13,17	13,55	16,77	16,77	7,00	26,20	61,30	60,80
C 18:2	8,69	9,08	12,75	12,55	9,38	9,69	12,21	12,06	6,30	14,50	53,70	59,60
C18:3	3,40	3,34	4,67	4,80	3,79	3,86	4,56	4,71	0,70	11,00	7,60	1,20
C20:2	-	-	-	-	-	-	-	-	-	0,70	-	-
Non Identified	0,41	0,98	0,62	0,28	0,45	0,44	0,65	0,26				

The composition of the oil of *pijuayo* shell obtained in this work, in function to the different experimental conditions is explained by the well-known fractionation ability of the pressure and temperature variation in the solvation capacity of the CO_2. It is observed also that the unsaturated fatty acids are first extracted, while the saturated fatty acids are extracted for the most part during the last third of the process. This means an advantage for the nutritional point of view, since recently the biological functions have been recognized of the ω-3 acids. The linoleic (18:2, ω-6) and linolenic (18:3, ω-3) acids are recognized as the bases of the acid series ω-6 and ω-3, and they are considered essential because they can not being synthesized by the mammals [7]. These fatty acids under successive desaturations and lengthening give origin to several metabolic products with important biological functions [8].

The high concentrations of the palmitic (C16:0) and oleic (C18:1) acids in the *pijuayo* shell coincides with those reported by different authors about the pulp oil [9]. It is necessary to indicate that in the saturated acids it was found small quantities margaric acid, which is found in low proportion in the canola oil (0,3%).

Table 4: Fatty acids content in experiment 2

Hours	Saturated		Monounsaturated		Poly-unsaturated	
	%	Accumulated	%	Accumulated	%	Accumulated
1	1,21	1,21	3,47	3,47	0,97	0,97
2	2,68	3,89	4,13	7,60	1,11	2,08
3	2,89	6,78	4,51	12,11	1,22	3,30
4	2,74	9,52	4,49	16,59	1,22	4,52
5	2,40	11,92	4,37	20,96	1,41	5,93
6	2,74	14,66	4,91	25,87	1,31	7,24
7	2,45	17,11	4,61	30,48	1,21	8,45
8	2,66	19,77	5,07	35,55	1,19	9,74
9	2,19	21,96	5,00	40,54	1,17	10,91
10	1,68	23,64	5,54	46,08	0,00	10,91
11	2,09	25,73	3,03	49,11	0,71	11,62
12	1,74	27,47	2,14	51,26	0,48	12,09
13	1,65	29,12	1,80	53,06	0,38	12,47
14	1,63	30,75	1,38	54,44	0,29	12,76
15	1,38	32,13	1,01	55,45	0,22	12,98

Behenic and tetracosanoic acids were also found which are present in a smaller quantity to 0,8% in the canola oil, soy oil, and saffron oil. The heptadecenoic acid (17:1) – unsaturated fatty acid - is also reported in the canola (2,5%); while the gadolenic acid (20:1) – another unsaturated - is found in very low concentration (less than 0,4%) in the canola oil, soy oil, saffron oil and coconut oil and, as the erucic acid (22:1) the percentage is smaller that of the canola oil (4.7%).

Finally, Soxhlet extractions of *pijuayo* shell during fifteen hours with hexane obtained yields of only 10,83%, what evidences a smaller capacity of extraction (around 20%) in relation to the experiment 2 with pressurized CO_2 (80,3 ± 0,4 bar and 26,8 ± 0,1ºC).

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