DEVELOPMENT OF A SHELLING METHOD TO RECOVER WHOLE KERNELS OF THE CUTIA NUT (*Couepia edulis*)[1]

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ABSTRACT - The kernel of the cutia nut (*castanha-de-cutia*, *Couepia edulis* (Prance) Prance) of the western Amazon, which is consumed by the local population, has traditionally been extracted from the nut with a machete, a dangerous procedure that only produces kernels cut in half. A shelling off machine prototype, which produces whole kernels without serious risks to its operator, is described and tested. The machine makes a circular cut in the central part of the fruit shell, perpendicular to its main axis. Three ways of conditioning the fruits before cutting were compared: (1) control; (2) oven drying immediately prior to cutting; (3) oven drying, followed by a 24-hour interval before cutting. The time needed to extract and separate the kernel from the endocarp and testa was measured. Treatment 3 produced the highest output: 63 kernels per hour, the highest percentage of whole kernels (90%), and the best kernel taste. Kernel extraction with treatment 3 required 50% less time than treatment 1, while treatment 2 needed 38% less time than treatment 1. The proportion of kernels attached to the testa was 93%, 47%, and 8% for treatments 1, 2, and 3, respectively, and was the main reason for extraction time differences.
Index Terms: instrumentation, nut, kernel, shelling, extraction method, Amazon.

DESENVOLVIMENTO DE METÓDO PARA DESCORTICAÇÃO DA CASTANHA DE CUTIA EM AMENDOAS INTEIRAS

RESUMO - A amêndoa da Castanha-de-cutia (*Couepia edulis* (Prance) Prance), originária da Amazônia Oriental e consumida pela população local, tem sido tradicionalmente extraída do fruto com auxílio de um facão, em um procedimento perigoso, que produz somente amêndoas quebradas. Aqui é descrito um protótipo para descorticação que permite a obtenção de amêndoas inteiras sem riscos ao operador. O protótipo faz um corte circular entre as duas extremidades da casca do fruto, perpendicular ao seu eixo principal. Foi avaliado o efeito de três pré-tratamentos do fruto: (1) controle; (2) secamento em forno imediatamente antes do corte; (3) secamento em forno, seguido de um intervalo de 24 horas antes do corte. O tempo total necessário para extrair e separar a amêndoa do endocarpo e da testa foi medido. O tratamento 3 produziu os melhores resultados: 63 amêndoas por horas, sendo 90% inteiras. A extração antecedida deste tratamento requereu 50% menos tempo de extração que no tratamento 1, enquanto o tratamento 2 requereu 38% menos tempo que o tratamento1. A proporção de amêndoas aderidas à testa foi de 93%, 47% e 8% para os tratamentos 1; 2 e 3, respectivamente, e foi a principal razão da diferença entre os tempos.
Termos para indexação: instrumentação, amêndoa, castanha, casca, método de extração, Amazônia.

INTRODUCTION

Concern about harmful consequences of deforestation has increased the interest in Amazonian forest products, especially non-wood ones. One of the latter is the cutia nut (*castanha-de-cutia*), *Couepia edulis* (Prance) (syn: Chrysobalanaceae), which may have market possibilities but at present is used only locally. A more efficient method of extracting its kernel from the hard nutshell would facilitate exploring the commercial potential of this forest resource.

The Food and Agriculture Organization of the United Nations (FAO, 1987) and Minetti & Sampaio (2000) have provided detailed descriptions of cutia nut tree, which is endemic in Brazil's eastern Amazon and occurs in the forest at the relatively high rate of six or more individuals per hectare. The species occurs in Amazonas State in the municipalities of Coari and on up to Tonantins in the middle Solimões river basin, and in the municipality of Tapauá in the middle Purus river basin. There are very few studies of cutia nut, which only in 1972 was described scientifically as a new botanical species (Prance, 1972, 1976).

The fruit of *Couepia edulis* is ovoid drupe, elliptic, and 4 to 5.5cm in diameter and 7 to 9 cm in length (FAO, 1987). Inside the fruit there is a single creamy-white ellipsoidal kernel, 4 to 5 cm in length and 2 to 3cm in diameter (FAO, 1987), covered by the testa (Figure 1). Around the kernel and testa is a somewhat thicker layer, the endocarp (Figures 1 and 2). Both endocarp and testa are rust-brown and easily manipulated and torn. The kernel, testa, and endocarp are enclosed by the fruit shell (mesocarp) (Figures 1 and 2), which is 8 to 10 mm thick, woody, fibrous, viscoelastic, and very difficult to open (Pessoa *et al*., 2004).

The kernel is eaten raw or toasted (FAO, 1987), grated to mix with manioc flour for a sort of pancake called *beiju* (Prance, 1972), or

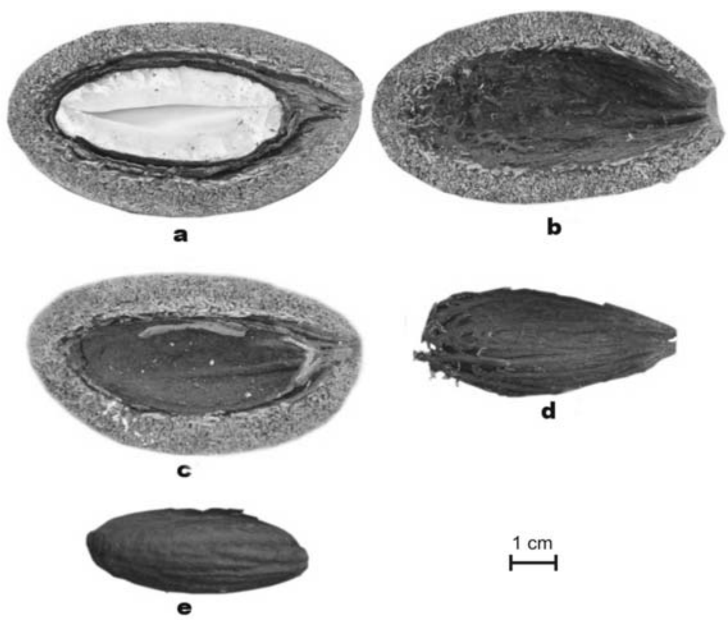

FIGURE 1 – The fruit of the cutia nut (*Couepia edulis*) cut along its main axis. a) From outside to inside: shell, endocarp and kernel; the left extremity of the endocarp accompanies the round shape of the kernel; the right extremity is angular, is not in close proximity to the kernel, and has a fibrous bundle easily grasped and broken off using pliers. The right extremity corresponds to the insertion point of the peduncle; b) inner side of the shell; c) shell and smooth inner side of the endocarp; d) endocarp outer side, which is rough and covered with relatively large fibers; e) testa outer side. (Photo: Johannes van Leeuwen).

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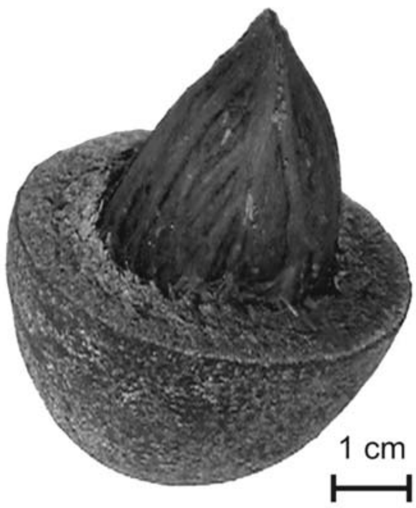

FIGURE 2 – Fruit of cutia nut (*Couepia edulis*) opened by the equipment shown in Figure 3. The lower half of the 8-10mm thick shell is shown. Shell's upper half with peduncle insertion point was removed. Endocarp's upper half (enclosing testa and kernel) is visible. Note its angular extremity.

eaten with coffee (E. Munõz, formerly of Tapauá, personal communication, 2003). Sometimes its oil is extracted and used for cooking or making soap (FAO, 1987). The kernel is approximately 73% oil and 9 to 17% protein.

The cutia nut tree produces numerous fruits, which drop when mature and are collected in large quantities by the population (FAO, 1987), can be stored in a dry place for months without noticeable deterioration (E. Munõz, formerly of Tapauá, personal communication, 2003).

Because of its kernel, which tastes like a Brazillian nut (*Bertholletia excelsa* H.B.K.), the cutia has been regarded for some time as a candidate for crop cultivation (FAO, 1987; MINETTI and SAMPAIO, 2000). But even before more recent research, the *Instituto Nacional de Pesquisas de Amazônia* (INPA) had already been engaged in the same study in the early nineteen-seventies. The work reported here is an outgrowth of that research.

To begin with, it had previously been thought that the cutia kernel might be marketed to compete with snacks such as Brazillian nuts, cashews (*Anacardium occidentale* L.), macadamias (*Macadamia integrifolia* Maiden & Betche), pistachios (*Pistacia vera* L.), and almonds (*Prunus dulcis* [Mill.] D.A.Webb). Unfortunately Spitzer *et al.* (1991) found two conjugated fatty acids (CFA) in cutia nut oil (19.0% á-licanic acid and 7.3% á-eleostearic acid) and observed: "Though there are few investigations about the biological effects of higher amounts of conjugated fatty acids . . . these seeds or their oils . . . cannot be recommended for human or animal nutrition."

Although health problems caused by the consumption of cutia nut kernels have never been reported, this possibility must be addressed, or plans for carrying out studies of the cutia nut as a potential food crop will have to be abandoned. Lately, CFA has been the object of much research attention (Christie, 2005), which may lead to more definitive conclusions on this issue. But there are two other aspects to be considered: since cutia nut oil dries fast, it has been regarded with interest in relation to the production of paint and varnish (Cavalcanti, 1947) and, recently, interest has been shown in the cutia nut as a potential biodiesel crop.

To more efficiently capitalize on the cutia nut an improved form of kernel extraction is needed. A method to extract the kernel without damaging it would also be useful to accelerate seed germination. Traditionally, the kernel has been extracted using a machete, which always results in the kernel being cut into two halves. The machete is placed at the spot of the shell where the peduncle was attached to the fruit, and a light blow is delivered. After that, the fruit is struck four to six times against a stone or tree stump, until the fruit divides in two along its longitudinal axis (Figure 1) and the two kernel halves can be removed.

Different kernel extraction methods have been developed for hard-shelled fruits such as cashew nuts (Dourado *et al*., 1999; Duvernevil & Haendler, 1973; Paiva *et al*., 2000), Brazillian nuts, and macadamia nuts (Braga, 1995; Liang, 1977, 1980), all of which have different characteristics. These methods show that pre-treatments, e.g., temperature and moisture variations, may facilitate shell opening and kernel extraction. In Brazil, for example, cashew kernel extraction includes the use of an autoclave to harden the nut shell, which becomes brittle and can be broken on impact. The shell also expands and disconnects from the kernel (Silva, 1998). Later, the kernel is kiln-dried to facilitate skin removal (Ferrão, 1995).

Developing a kernel extraction method for the cutia nut required studying its morphological characteristics (Pessoa *et al*., 2004). Compression tests employing up to two tons showed that the nut shell has high viscoelasticity, which indicated that the use of impact or pressure would not be effective. In addition, wetting and warming the fruit did not alter this shell characteristic satisfactorily. As the fruits are fairly symmetrical around the main axis, Pessoa et *al*. (2004) proposed to open the shell by cutting it on a transversal plane perpendicular to the axis. The equipment for this method and the test it allows are described in this article.

MATERIAL AND METHODS

Beginning in 2003, cutia nuts were collected at the Experimental Station for Tropical Fruit Growing of the National Institute for Amazonian Research (INPA), Manaus, Amazonas, Brazil. The cutting equipment was developed and tested at Embrapa Instrumentation Center for Agriculture (*Embrapa Instrumentação Agropecuária*- EMBRAPA) São Carlos, SP, Brazil.

The method presented here requires a circular incision penetrating close to the kernel in the fruit shell, and then cutting the shell into two halves. These are detached from each other, and the kernel is separated from the endocarp and testa. This method was tested by the first author using a machine prototype shown in Figure

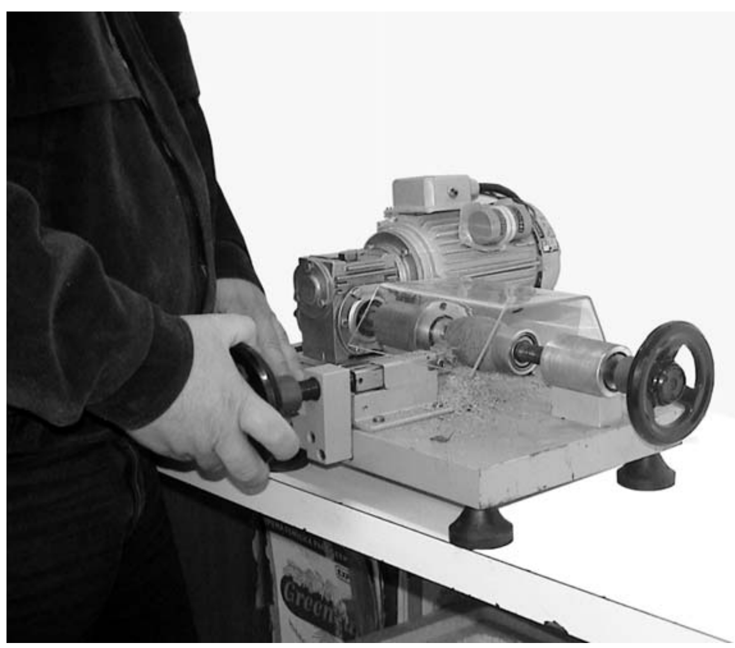

FIGURE 3 – Equipment used to cut the shell of cutia nut (*Couepia edulis*). The right hand wheel secures the fruit. The geared motor rotates the fruit around its main axis. With the left hand wheel the operator moves the grinding wheel towards the rotating fruit, makes an incision in the shell, and cuts it into two parts.

3. A toothed cup was fixed to the axis of a geared motor (1/8cv/ 175rpm). Aligned to the axis a freely rotating conical tip was placed. Using a lead screw and a hand wheel the fruit was placed between the toothed cup and the conical tip. With the fruit rotating an incision was made along a transversal plane perpendicular to the main axis by an operator using a lathe tool, which was operated with the same lead screw and hand wheel previously referred to. While the geared motor rotated the fruit, the lathe tool penetrated approximately 11 mm through the shell but stopping short of the kernel. When necessary, auxiliary tools were used: a screwdriver to separate the two shell halves, pliers to rotate the tip of the endocarp so as to break it (Figures 1 and 2), and a blade to peel off the endocarp and testa.

Three lots of 30 fruits were chosen at random to compare the following treatments: (1) kernel extraction without pre-treating fruits (the control); (2) kernel extraction immediately after oven-drying fruits for 16 hours at 100°C; (3) kernel extraction after oven-drying fruits for 16 hours at 100°C, after which they remained for 24 hours at approximately 25°C and air humidity of 30%.

The weight of each fruit and the length of its main axis were measured at the beginning of the experiment. Fruits in treatments 2 and 3 were weighed immediately after oven drying; fruits of treatment 3 were weighed again 24 hours later, just before being cut. For all fruits the following data were recorded: time necessary to obtain the kernel; state of kernel (whole or broken); whether or not the testa was attached to the kernel, and whether or not the endocarp was attached to the nut shell; whether or not auxiliary tools were necessary. The time used for kernel extraction was analyzed with analysis of variance for a one-way classification (Snedecor & Cochran, 1980). Tuckey's test for multiple comparisons of means was used to determine which treatments were significantly different at the 5% level (Gomes, 1978). The other observations were analyzed with the chi-square test for a 2x3 contingency table (Snedecor e Cochran, 1980), while pairs of treatments were compared with the chi-square test for a 2x2 contingency table.

RESULTS AND DISCUSSION

The described incision method successfully opened the shell and obtained a whole kernel. An experienced operator would note the alteration in sound when the lathe tool has penetrated the shell and begun cutting the endocarp. When that happens, the motor should be stopped immediately to avoid damaging the kernel.

After cutting, the two shell halves usually are still connected by some inner shell fibers, as the fruit is not perfectly symmetrical. In such cases shell halves were separated using a screwdriver as a lever. This detached one shell half, while in most cases the endocarp containing the kernel remained fixed to the other shell half. In every case the loose shell half was that which had been connected to the peduncle. Consequently, the extremity of the endocarp being exposed terminated in a point (Figures 1 and 2) that could easily be grasped and broken off with pliers without causing damage to the kernel (Figure 1). Very frequently the testa was attached to the kernel and required loosening with a blade. Occasionally the endocarp and testa could be separated from the kernel even without using tools.

Fruit length varied between 7.3 and 9.2cm (mean 8.3 cm), closely agreeing with data of the FAO (1987). In all three treatments no relation was found between extraction time and fruit weight, indicating that extraction time does not depend on fruit size. Differences in extraction time for the three treatments were statistically significant (Table 1). The mean extraction time of the nuts, which were oven dried and cut immediately afterwards, was 38% less then that of the control treatment, while kernel extraction of the nuts cut 24 hours after being oven dried took 50% less time then the control treatment.

Auxiliary tools (pliers, screwdriver, and blade) were useful in all treatments and almost always screwdriver use was necessary. The pliers were necessary for severing tough endocarp fibers and the blade was very useful even when the testa was not attached to the kernel. Oven drying made the testa and endocarp brittle, thus facilitating kernel extraction.

The time necessary for kernel extraction included: shell cutting, separation of shell halves, kernel removal, and elimination of endocarp and peel. Shell cutting time did not change significantly with treatments, although the control treatment seemed to require greater cutting power. Between 15 to 30 seconds were needed for

TABLE 1 - Results of cutia nut (*Couepia edulis*) kernel extraction using a circular incision after different pre-treatments of the nuts.

Treatment [(1)]	Number of nuts	Mean extraction time [(2)] (seconds)	Whole kernel (%)	Testa attached to kernel [(2)] (%)	Endocarp attached to shell [(2)] (%)	Use of auxiliary tools (screwdriver, pliers, blade) (%)
(1) Control	30	113 a	70	93 a	100 a	93
(2) Oven drying; cutting immediately afterwards	30	92 b	73	57 b	80 b	77
(3) Oven drying, followed by 24-hour interval before cutting	30	57 c	90	8 c	97 a	83
P [(3)]		0,000	0,136	0,000	0,008	0,200

(1) (1) control, kernel extraction without pre-treating the fruits; (2) kernel extraction immediately after oven drying the fruits for 16 hours at 100°C; (3) kernel extraction after oven drying the fruits for 16 hours at 100°C after which they were left for 24 hours, at approximately 25°C and 30% air humidity.

(2) Values of a column with the same letter are not significantly different at the 5% significance level.

(3) Probability of obtaining equal or higher values under hypothesis zero (no differences between the treatments).

TABLE 2 – Time for cutia nut (*Couepia edulis*) kernel extraction in relation to testa-kernel binding.

Treatment	Number of nuts [(1)]		Extraction time [(2)] (seconds)	
	Testa attached to kernel	Testa not attached to kernel	Testa attached to kernel	Testa not attached to kernel
(1): Control	28	2	117 ± 47%	54 ± 20%
(2): Oven drying, cutting immediately afterwards	16	12	112 ± 55%	71 ± 33%
(3): Oven drying, followed by a 24 hours interval before cutting	2	24	88 ± 63%	55 ± 21%

(1) The values refer to 84 nuts, six less then in table 1. This difference is caused by the fact that in six cases it was not registered if the testa was attached, or not, to the kernel.

(2) Mean ± coefficient of variation.

shell cutting and separation; the remaining steps required more time.

For all three treatments extraction time was greater for fruits whose skin had adhered to the kernel (Table 2). In these cases, a blade was necessary to peel back the testa, which increases extraction time and almost always marks the kernel surface. The number of fruits whose testa was attached to the kernel varied with the treatments and influenced the mean extraction time. The control treatment had the highest percentage of fruits with kernel and testa attached to each other and, thus, the highest extraction time. Treatment 3 (oven drying, followed by a 24-hour interval before cutting) produced the lowest percentage of fruits with the testa attached to kernel and, consequently, this treatment's extraction time was shortest (Table 1).

Before drying the 90 nuts, their weights varied from 48.3 to 91.0g (mean 68.7 g). After drying, the fruits of treatments 2 and 3 had lost 9.5%±0.6 (mean ± standard deviation) and 9.5%±0.5 respectively from their original weight. After 24 hours at ambient temperature the weights for treatment 3 increased 4.0%±0.7, resulting in a net 5.5%±0.8 weight loss. The decrease in fruit moisture followed by air vapor absorption and temperature changes probably created mechanical stresses that separated kernel and testa in a larger number of fruits. Certainly this resulted from changes during heating and cooling in the chemical bonds at the kernel-testa interface, and the variations in kernel and testa volume during the temperature changes. Drying followed by 24 hours at ambient temperature also made testa and endocarp more brittle, which facilitated kernel removal and produced 20% more whole kernels than the control did, but this difference was not large enough to be statistically significant at the 5% level (Table 1). Drying also changed the organoleptic properties of the kernel, which became crisper and tastier. It was further observed that after removing one shell half, a 15-second exposure of the endocarp to a Bunsen flame made the endocarp and testa still more brittle, which greatly facilitated kernel extraction.

With the tested equipment, the lathe tool could only be moved perpendicularly to the main fruit axis. This hindered kernel extraction of only one of the 90 fruits, because too small a part of the kernel was available for being grasped manually and removed. Finally, this cutting method presented a very low accident risk.

CONCLUSION

The circular cutting of the cutia nut shell proved capable of yielding a high percentage of whole kernels, especially when the fruits were previously dried at 100 °C for 16 hours, followed by exposure to air at ambient temperature for 24 hours. In most of the fruits submitted to this treatment, the testa detached from the kernel, resulting in a reduced kernel extraction time (63 kernels per hour) and a larger percentage of whole kernels with improved taste and crispness. Exposure of the endocarp to a flame following removal of one shell half is worth evaluating as an alternative to pre-treatment of the nuts.

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