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Drying the African Palm Tree (*Borassus aethiopum*, Mart) Fruits in View of Producing Edible Flour

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Abstract: In order to valorize the rapidly deteriorating fruits of the palm tree *Borassus aethiopum* Mart under hot and humid climate, drying assays for preservation were carried out. Fruits morphological parameters (weight, diameter and pulp thickness) from two most producing agro ecological zones of Cameroon were measured. Pulps obtained upon pulping the fruits were cut out and dried using an electric dryer under mild conditions (40°C and 20% drying air humidity). Physico-chemical and functional characterization of fresh and dried pulps allowed evaluating the influence of drying on some pulp components. Morphological characteristics of fruits were not significantly different ($p<0.05$) from one origin zone to another. Fruits average diameter and pulp thickness were 14 cm and 8 mm, respectively while average weights varied between 1270.04±16.69 and 1324.55±85.99 g. Average yield in flesh was 38%. Drying kinetic obtained was classical and revealed that the fifth hour was the necessary time of drying to obtain pulps with constant characteristics and acceptable maximum residual moisture content of 15%. In addition, at this time the pulps contained 60 and 55% of their initial total carotenoids and vitamin C contents, respectively. The flour obtained after milling and sieving comprised mostly particles of 250-500 µm sizes and showed appreciable physico-chemical and functional properties: Water Absorption Capacity (WAC) of 313-407%; Solubility Index (SI) of 39-51%; Fiber content (FB) of 14-30% DM. These results demonstrate the feasibility of flour production from pulps of this Cameroonian palm tree.

Key words: *Borassus aethiopum*, valorization, preservation, flour, physico chemical, palm tree

INTRODUCTION

In developing countries, important amount of fruits and vegetables are deteriorated and lost after the harvest. These losses could be explained by inappropriate preservation methods and also by lack of information on economically profitable processing methods that can improve living conditions of farmers. Among the numerous fruits exhibiting high postharvest losses in the sub-Saharan zone are those from palm tree (*Borassus aethiopum* Mart). It is a tree growing in semi-arid and sub-humid zones of Africa (Cretenet *et al*., 2002). These trees are found in groups of 60-120 feet per ha and produce about 150-350 fruits each per season (year). The fruits weight is between 1.5 and 2 kg, giving 15-40 tons of fruits per ha. However, this production is not entirely recovered since 60% are lost within 2 weeks upon harvest. These losses are essentially due to the important water and free sugars contents of the fruits. In these conditions, the deterioration of fruits is enhanced by the hot (32-38°C) and humid (70-90% RH) climate that prevails during the harvesting season. *Borassus aethiopum* Mart is an Arecaceae also known in Africa as the mother of trees or as the savannah's guard. This tree's height is up to 25 m and has a right and smooth trunk surmounted by a big fanlike leaves crown (Fig. 1a, b). The area of natural distribution of this species, covers countries like Senegal, Gambia, Bissau-Guinea, Guinea, Sierra Leone, Liberia, Ivory Coast, Burkina Faso, Benin, Mali, Togo, Niger, Nigeria, Cameroon, Chad, Sudan, Central Africa Republic, Democratic Republic of Congo and Ethiopia (Cretenet *et al*., 2002; Harris and Ray, 1935; Leakey, 1996; Phillips *et al*., 1988; Vivien and Faure, 1996).

In Cameroon, the area of distribution is wide and is situated between the Lake Chad basin and the foot of Mount-Cameroon Mountain passing through the Benoue basin. In the northern region, important populations are found around Poli and Rey-Bouba while in the Adamawa

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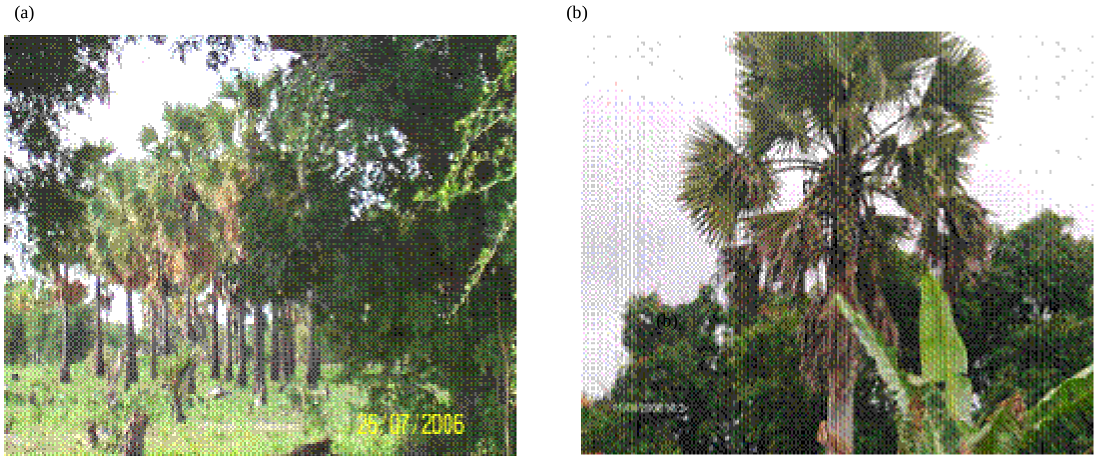

Fig. 1: a) Partial view of a palm grove at Logone Birni, b) Palm tree at the beginning of production

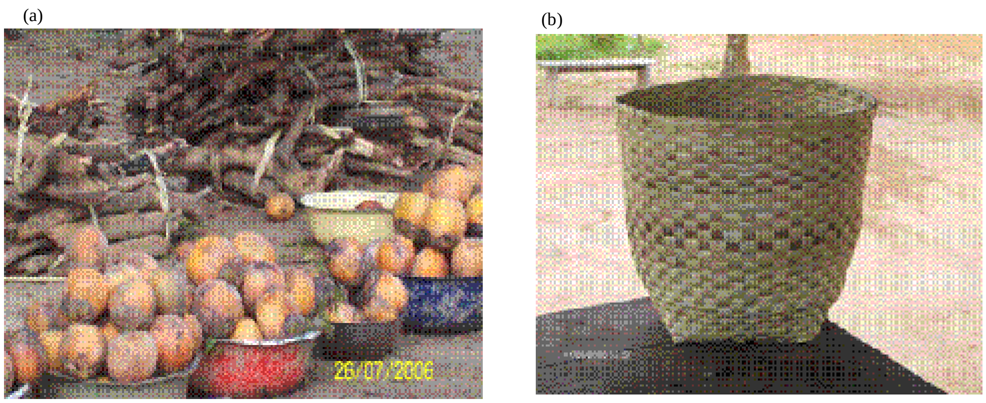

Fig. 2: a) A palm tree leaves made basket, b) Palm tree fruits on sale

highlands plant density is important in the Vina valleys and Mbere division. As a consequence of this geographic distribution, production and harvesting periods are possible throughout the year depending on the area. Very few trees are found in the South Cameroon secondary forest. *B. aethiopum* is a plant with multiple uses implying all its parts. With regard to transformation of *B. aethiopum*, trunk, leaves and fruits are used by local craftsmen (Fig. 2a) and are at the center of important activities thus generating appreciable incomes. Its fruits with fibrous mesocarp are gathered in tightened bunches. They are ovoids or smooth globulous and fibrous drupes from 15-20 cm in diameter. Their color at maturity is yellow, orange or slightly reddish (Fig. 2b). A very sweet, viscous and scented juice is extracted from the ripe fruit that is further incorporated in millet gruel or in millet cakes. The fruits pulp has an output in flesh of 38% of the fruit total weight. It is rich in total sugars and in fibers with average contents of 25.5% (dry matter). It also contains essential minerals and vitamins with the following contents (mg/100 g, fresh matter): calcium (107-108), phosphorus (560-567), magnesium (20-21), iron (2-2.2), vitamin C (134-171) and total carotenoids (26-28). The fruits physico-chemical composition, yellow-orange color and very pronounced pleasant aroma are the main characteristics exploited by food industries in view of the economic valorization of this interesting natural resource. However, the problem of the palm fruit remains its high perishability. It is therefore important to screen for efficient preservation methods in view of greater and more profitable valorization. Drying is among the most spread and used preservation techniques in developing countries. It helps in increasing the preservation time of many products by reducing the water activity (Bimbenet, 1984) especially when the dried products are stocked in tight packaging. In Senegal dried fruits of the palm tree are already used in animal feeding (Bonkoungou *et al*., 1998).

The present study was carried out to investigate the ability of Cameroonian palm tree fruits to produce edible flour. To this effect, technological (water absorption capacity, solubility and fibers) and physico-chemical (total sugars, soluble sugars, crude proteins, total carotenoids and vitamin C) properties were determined for dry fruits to verify the following three hypotheses:

- Variations of the morphological parameters of palm tree fruits are related to the source
- Under the combined effect of time and temperature, drying can influence the physico-chemical properties of dried pulp
- Granulometry of the flour obtained by grinding and sieving of dried pulps influences the flour characteristics, particularly the distribution of its technological properties

MATERIALS AND METHODS

Plant material sampling: Fruits of *Borassus aethiopum* were collected in localities of Kousseri (Logone and Chari division-Far-north region of Cameroon, 12°04'North latitude and 15°01'East longitude) and Wakwa (Vina division-Adamawa region of Cameroon, 7°08 ' of North latitude and 13°10' East longitude). These two sampling localities were chosen because they are in the heart of two most important production regions, namely the sahelo-soudanian (Kousseri) and soudanian (Ngaoundere) agro-ecologic zones. On the eve fruit sampling, spaces around palm tree feet were cleaned to take away old fruits. The following day, early in the morning, mature fruits were collected at the food of each tree, kept in iceboxes and transported to the laboratory of the University of Ngaoundere (15 km from Wakwa and 700 km from Kousseri). Upon reception in the laboratory, fruits were washed and sorted out by visual appreciation of the yellow-orange color and palpation of the fruit to constitute shares with similar maturity degree and to eliminate non mature or deteriorated fruits. Generally, this study considered tender and yellow-orange palm tree fruits as mature. The sorted out fruits were further washed and wiped with clean cloth cotton to constitute samples for subsequent analyses.

An electric drier CKA-2000 AUF (1999) was used. The drier had forced convection, constant air flow (2 m sec^{-1}), thermoregulated (20-60°C) and 6 kW power of heat. Its maximal load was 15 kg of fresh products. The drier height was 1.7 m while its depth and width were respectively 52 and 40 cm. The opening air exit is circular and had a diameter of 10 cm. An electric Culatti Type MFC grinder was used to grind the dried pulp. About 5 sieves of various stitches (1000, 500, 400, 250 and 160 μm) were stacked up to obtain pulp powder. A 1/1000th precision type XM 360 PRECISA balance was used for weighing samples.

Samples preparation: Thirty whole fruits from two sources previously chosen were calibrated by measuring the mass of fruit (mf) using a 1/1000th precision balance, the diameter (df) with a measuring tape and the thickness of pulp (tp) with a caliper square. This last measurement was carried out by introducing a long needle (15 cm) in the flesh until it reached the core (marked by a hardening which prevented the penetration of this needle). Penetration distance of the needle was measured with a ruler to determine the pulp thickness. The fruits were then peeled and pulped using a stainless knife to separate the pulp (mass mp), the skin (mass ms) and the core (mass mc). The core was cracked with a hammer and the almond of mass (ma) was separated from the shell mass (sm) by scraping with a knife. The fruit pulp obtained after these preliminaries stages were distributed in two shares. The first made up of the Fresh Pulp (FP) was used for physico-chemical analyses and the second was dried at 40°C in view of obtaining Dried Pulp (DP) and of determining drying kinetics.

Drying of the pulp: For drying, pulps from each source were cut up in pieces (5 g) of average dimension (50×20×8 mm) with a stainless knife. On the big tray of the drier, 3 small trays containing each 10 g of pulps are disposed. These three small trays constitute replicates. Then, the trays containing samples were introduced in the dryer for 48 h. The dryer's inside temperature was maintained at 40°C by the in-built thermostat while the relative moist of the circulating air (speed 2 m sec^{-1}) was maintained at 20%. The operating conditions were chosen to approach those used by peasants in traditional solar drying. Successive weighing at increasing interval of time with a weak incrementing at the beginning of the operation was done, followed by progressive display with time (0, 0.5, 1, 2, 3, 5, 10, 16, 24, 36, 48 h). Evolution of the mass of trays containing with time was noted until this mass stabilized, thus marking the end of drying. The results helped in following the evolution of instant water content compared to the initial water content (normalized values). The dried pulps were withdrawn from the dryer, ground during 30 sec with the grinder as previously indicated. The powder obtained was divided in two shares: one for physico-chemical analyses and the other was sieved to get five fractions of powders (PS Ø) with different granulometries: Ø>500 μm, 500 μm>Ø>400 μm, 400 μ>Ø>250 μm, 250 μ>Ø>160 μm and Ø<160 μm.

Physico-chemical analyses: Water Content (wc) and total ashes obtained by incineration of defatted flour were performed using normalized method (AFNOR, 1982). Soluble Sugars (SS) were extracted with water while Total Sugars (TS) were obtained by acid hydrolysis with HCl and their contents were analyzed according to Fisher and Stein (1961). For the raw protein, samples were first mineralized according to the method of Kjeldahl (AFNOR, 1982) and total nitrogen was measured according to Devani *et al.* (1989). Fiber content and carotenoids were quantified according to the method described by Wolff

(1968). Vitamin C was extracted using the technique of Harris and Ray (1935) and measured according to Evered (1960). The apparent and real water absorption capacity (WACa, WACr) and solubility were performed according respectively to methods of Phillips *et al.* (1988) and Anderson *et al.* (1969).

Statistical analysis: Data on generated by the three replicates are expressed in mean±standard deviation. The means were compared by Analysis Of Variance (ANOVA) and where significant differences existed ($p<0.05$) treatments were compared by the Duncan multiple test of (SPSS, 1993) to regroup samples according to the similar characteristics.

RESULTS AND DISCUSSION

Morphological characterization of fruits: The morphological characteristics of fruits were measured in order to look for possible variations between physical parameters of fruits from two origins and to master the mass distribution of different parts of the fruit. These differences are necessary for calculation matters balances of transformation processes. The average results are shown in Table 1 showed that in spite of the variability observed between fruits of same origin is appreciated from the calculated standard deviation. The analysis of variance did not a highly significant difference ($p<0.05$) between the studied morphological parameters and the origin/source. Independently of the source, fruits had average diameter between 13 and 14 cm, a pulp thickness of 8 mm, for an average mass between 1200-1400 g. The mass distribution in different parts related to the total mass of fruits was as follow: pulp (35-38%); skin (11-12%); core (50-52%); shell (21-22%); almond (29-30%).

The inter-shares analysis of relations between studied parameters, showed the existence of a perfect, positive and significant correlation ($p<0.05$) between the mass of the fruit and masses of the core ($r = 96$) on one hand and between the mass of the fruit and the mass of the pulp ($r = 93$) on the other hand. Correlations between different parameters helped to orient the choice of the fruit's quality in a perspective of production. This study suggests that fruit's origin could not be considered as determining element in the choice and the conduct of transformation processes. In addition, it would be judicious to choose fleshy fruits (important output in flesh) on the basis of their masses rather than their diameters.

Drying kinetic: Drying was achieved under moderate conditions (temperature ≤40°C), relative humidity (≤20%) and air circulation speed (2m sec^{-1}). Recorded data with a thermohygrometer and an anemometer are close to that in artisanal solar dryers. Regular weight measurements of drying samples were used to draw drying kinetics. Values of instant water contents Xe (t) recorded were normalized in relation to initial water contents X0 of samples (Xe(t)/X0) in order to appreciate and to compare water removal with time (Fig. 3). As shown by the curves of Fig. 3, water removal speed in the pulp, independently of the origin was regular and very important for the first 5 h of drying, corresponding to a drying with constant rate (Cheftel *et al.*, 1983).

Table 1: Morphological characteristics and mass distribution of fruits from Kousseri and Ngaoundere

	Area of origin	
Parameters	Zone 1 (Kousseri)	Zone 2 (Ngaoundere)
Average diameter (cm)	13.85±0.32[a]	13.56±0.49[a]
Pulp size (cm)	0.82±0.03[a]	0.82±0.05[a]
Whole fruit mass (g)	1324.55±85.99[a]	1270.04±116.69[a]
Pulp mass (g)	511.88±36.91[b]	449.19±46.910[a]
Nucleus mass (g)	658.83±47.57[a]	659.76±71.40[a]
Skin mass (g)	158.32±32.74[a]	154.72±30.32[a]
Shell mass (g)	291.40±12.32[b]	270.36±9.26[a]
Almond mass (g)	395.77±20.45[b]	379.48±16.12[a]
Pulp (%)	38.60±1.07	35.22±1.19
Nucleus (%)	43.43±2.40	44.83±1.98
Skin (%)	11.93±1.51	10.33±1.91
Shell (%)	20.2±4.10	19.01±5.03
Almond (%)	26.80±1.46	25.84±1.08

Values on the same line with the same letter as superscript are not significantly different at 5%

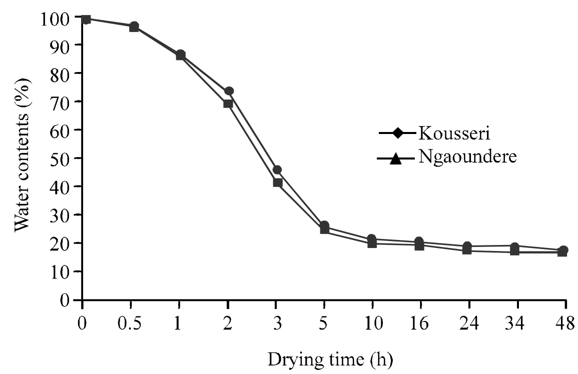

Fig. 3: Evolution of normalized water contents with drying time

During this period, a loss of about 80% of the initial water of the product was recorded. After the 5th h, the rhythm of water removal was progressively slowed down to reach equilibrium from the 10th h. Thereafter, the final product used for flour production contained only 10% of its initial humidity. The analysis of variance did not show a significant difference ($p<0.05$) between water content at the 5th h and the 10th h. Thus, the 5th h can be considered as the necessary time to reach the critical water content of pulps that marks the beginning of unavailability of the free water generally associated with

Table 2: Composition in g/100 g DM of palm tree fruits pulps before and after drying (48 h)

	Substrat			
	Fresh pulp		Dry pulp (48 h at 40°C)	
Parameters	Kousseri	Ngaoundere	Kousseri	Ngaoundere
Water content	81.38±1.94	79.13±0.64	9.37±0.31	10.05±0.25
Total sugars	26.95±1.13	24.02±1.07	25.07±1.46	22.86±1.57
Soluble sugars	21.94±1.12	20.17±1.03	20.48±1.95	19.01±1.52
Crude proteins	4.06±0.23	3.92±0.10	4.33±0.21	4.23±0.32
Carotenoids (*)	137.10±4.52	133.05±4.17	79.14±3.56	81.07±2.86

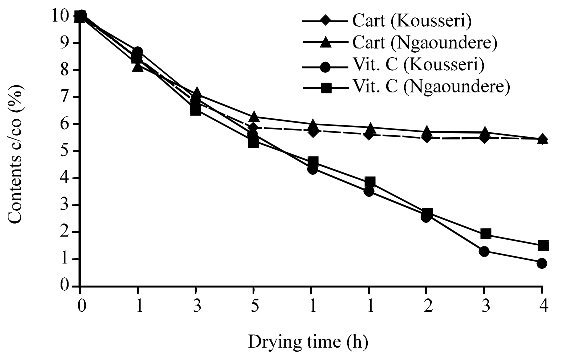

Fig. 4: Influence of drying time on Vitamin C and carotenoids contents

food spoilage. It was not necessary to continue the drying operation beyond this time since a product with constant characteristics could be obtained. The cracking aspect and a maximum residual water content of 15% are considered to allow good preservation and grinding abilities.

Drying influence on the composition of the pulp: In order to evaluate the drying influence on the quality of product, a comparison was made between the composition of the pulp before and after 48 h of drying. Results are shown in the Table 2. A finer survey was carried for constituents mostly affected by drying conditions, vitamin C and carotenoids which are heat and light sensitive. As shown by Fig. 4, carotenoids and vitamin C were highly influenced par drying. Respective losses of 37-41% and the 44-46% were noted recorded at the end of the first 5 h. These losses could be due to oxidization reactions by oxygen, catalysed by light, heat and presence of water. Vitamin C is more sensitive to the oxidization than carotenoids (Cheftel et *al*., 1983). When drying is stopped at the 5th h, the product still contained, respectively 59-60 and 54-56% of the initial total carotenoids and vitamin C contents. These results are similar to those obtained by Kameni *et al.* (2003) who dried mango pulp at 50°C. These authors revealed rates of vitamin C conservation higher than 56%.

Granulometric analysis and characterization of flour: Granulometric analysis of flour obtained by grinding and

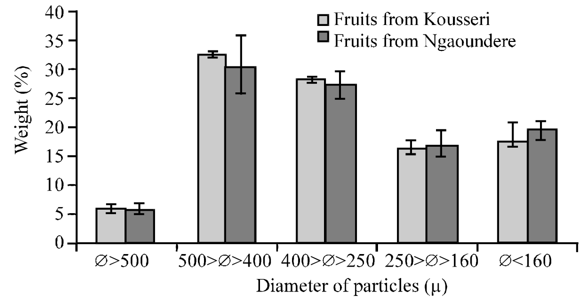

Fig. 5: Granulometric distribution (% of the mass) of palm tree pulp fruits flour

sieving of the dried pulp was achieved to appreciate the distribution of particle size and to study characteristics related to these particle size. Granulometry of flour is a fundamental characteristic closely linked with all unit operations of separation, mixing, transportation and transfer to which flour can be submitted. It constitutes a determining parameter in the physico-mechanical phenomena related to ingestion and digestive transit of food particle but also in exchange phenomena and physical reactivity (migration of water, rehydratation, rheological out-flow, homogenization, scattering, solubilization) (Melcio, 2000).

The granulometric analysis (Fig. 5) showed that whatever the fruits origin, fractions 500 μm>Ø>400 μm and 400 μm>Ø>250 μm are dominating with proportions higher than 30%. Finest fractions Ø<160 μm are lower than 20% whereas the largest fractions are <5%. The sample fractions which granulometry were between 500 μm>Ø>250 μm, represented 57-60% of the total mass, against 5-6 and 32-35%, respectively for granulometry fractions Ø>500 μm and Ø<250 μm. Two sub-classes could be distinguished within the majority fraction: those between 500 μm>Ø>400 μm (30-32% of the total mass) and those between 400 μm>Ø>250 μm (27-28%). Similarly, in the fine class, sizes between 250 μm>Ø>160 μm (15.5-16%) and sizes lower than Ø<160 μm (17-19%) were distinguished. Apparent and real water absorption capacities (WACa, WACr) and Solubility Index (SI) were measured according to the granulometry (Fig. 3). Water absorption capacities (WACa, WACr), Fibers contents (FB) and Solubility Indexes (SI) varied with particles size. Water absorption and fibers content increased proportionally with particles size.

A reverse trend was observed for solubility index. The highest water absorption capacities and fibers contents (WACa = 407.1±0.42%; WACr = 853.75±16.01%; FB = 29.75±0.08%) and the lowest solubility index (SI = 39.9±1.77%) were recorded for the fractions with the most important granulometry (Ø>500 μm). High ashes content (AC = 3.96±0.01 g/100 gMS) were measured for the finest particles fractions, revealing a higher minerals concentration. Similar results were obtained by Mongeau and Brassard (1982) and by Iwuoha (2004), respectively on wheat bran and on saturated vapor dried yam tubers, showing that water absorption capacity increased with the particles size. Seyer (2005) noticed that wheat particles size influences food fibers content: the finest the particles, the lesser the total fibers. The analysis of variance did not reveal any significant difference ($p<0.05$) between studied parameters for fruits from the two localities, confirming that the origin of the raw material does not influence the choice and the processes of transformation.

CONCLUSION

This study demonstrated the feasibility of the production of pulp flour from the palm tree (*Borassus aethiopum*, Mart.) fruits by drying in soft conditions. A finer study is necessary to determine the optimal conditions of drying and the qualitative and quantitative antinutritional factors. The respect of operating conditions can lead to the production of flour with acceptable technological characteristics and which is economically exploitable. The obtained flour can be used alone or mixed to other flours of local cereals of current consumption to improve or to balance their food values. It can also play a role in increasing sweet taste, aroma and color or transformed into other products with high added value.

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