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# Chemical composition and nutritive value of peach palm (*Bactris gasipaes* Kunth) in rats

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**Abstract: The peach palm (*Bactris gasipaes* Kunth) is the starchy fruit of a palm tree widely cultivated in Central and South America. The present study aimed at determining its chemical composition and its nutritive value in rats. The average chemical composition of 17 samples was as follows: 410 g kg$^{-1}$ water and, in g kg$^{-1}$ of dry matter (DM), 54 g crude protein, 114 g oil, 39 g neutral detergent fibre, 716 g starch, 21 g sugars and 18 g ash. The main variability was observed for the oil (60–180 g kg$^{-1}$ DM) and starch (590–780 g DM) contents. The proteins contained, on average, in g kg$^{-1}$ of proteins, 49 g lysine, 13 g methionine, 19 g cysteine, 39 g threonine and 7 g tryptophan. The mineral fraction contained, per kg DM: 1.0 g Ca, 0.8 g P, 0.6 g Mg, 0.3 g Na, 44 mg Fe, 4 mg Cu and 10 mg Zn. The digestibility of four peach palm genotypes was determined in rats fed a diet composed of 350 g kg$^{-1}$ of peach palm and 650 g of a control diet based on maize and soybean meal. The digestibility of DM, energy, starch and protein of peach palm alone reached, on average 91, 87, 96 and 95%, respectively. No difference was observed between varieties, except for starch ($p < 0.05$). On average, peach palm contained 51 g of truly digestible protein kg$^{-1}$ DM and 3.691 kcal digestible energy kg$^{-1}$ DM. A growth trial was also carried out for 1 month on rats (initial weight: 78 g) fed a diet containing 0, 200, 400, 600 or 800 g peach palm kg$^{-1}$, at the expense of a diet composed of maize starch and casein. The growth rate of the rats decreased ($p < 0.05$) as the peach palm concentration increased. The growth decrease was due to a decrease ($p < 0.05$) in DM intake and to the lower quality of the peach palm protein. It is concluded that peach palm is mainly an energy source for humans and animals. It is poor in protein and minerals but can be consumed in large amounts.**

**Keywords:** peach palm; *Bactris gasipaes*; chemical composition; nutritive value

## INTRODUCTION

The peach palm, pejibaye or chontaduro (*Bactris gasipaes* Kunth, Aracaceae) was the most important palm tree of pre-Columbian America and constituted the main crop of the Amerindians living in the humid tropics.[1] Its natural distribution extends from Panama to Bolivia, in regions with an altitude lower than 1000 m, mean annual rainfalls between 2000 and 5000 mm and annual mean temperature over 22 °C. Nowadays, it is widely cultivated outside its original region.

Peach palm is grown for its fruit and for palm heart production. The tree produces a large raceme composed of 50–100 drupes (Fig 1) with a green, yellow or red endocarp, a starchy mesocarp and a hard seed. The fruit weight ranges from 10 to 200 g and one raceme can weigh up to 10 kg.

Interest in peach palm is growing in many countries, because the fruit is a valuable source of energy and carotenoids for humans[2] and animals and as much as 25–30 tonnes ha$^{-1}$ year can be produced, with a theoretical potential of 50–55 tonnes.[3] Moreover, it is quite poor in antinutritional factors, namely trypsin inhibitors and calcium oxalate.[4–6] However, despite its interest and status as a staple food in many regions of Latin America, little data on either its composition or its nutritional value is available in literature.

There is a wide diversity among both cultivated and wild varieties. The literature mentions oil contents ranging from 20 to 620 g kg$^{-1}$ DM in wild populations and from 40 to 180 g in cultivated varieties.[7] The oil composition is also quite variable, with palmitic acid and oleic acid contents ranging from 18 to 45% and 41 to 62% of the total, respectively.[2,7]

The aim of the present work was to study thoroughly the chemical composition and the nutritive value in rats of different peach palm varieties and to evaluate the range of variation of the

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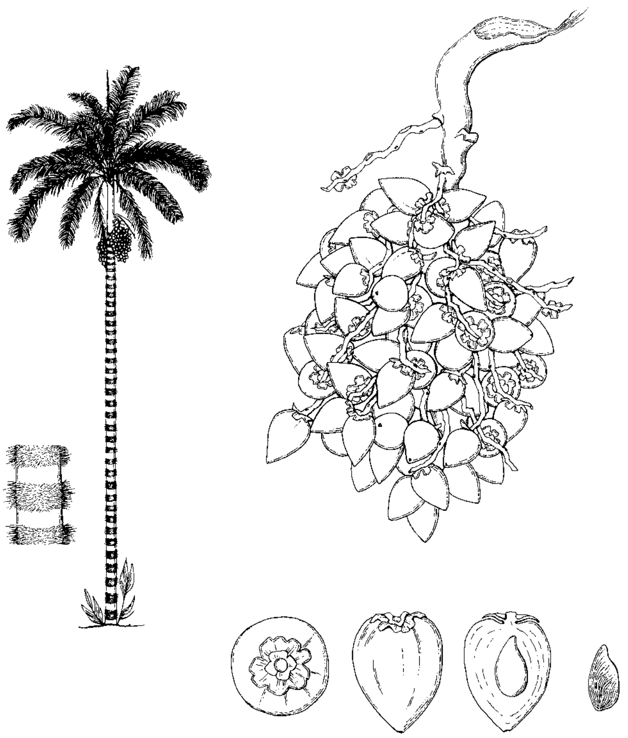

**Figure 1.** Tree, raceme and fruit of peach palm.

**Table 1.** Origin and description of the 17 samples of peach palm raceme

| No | Origin[a] | Colour | Weight[b] (g) | Volume[b] ($cm^3$) | Length[b] (mm) |
|---|---|---|---|---|---|
| 1 | Rain forest | Yellow | 35 (2) | 27 (3) | 39 (5) |
| 2 | Rain forest | Yellow-orange | 51 (5) | 43 (4) | 50 (3) |
| 3 | Rain forest | Orange-green | 20 (2) | 18 (2) | 29 (2) |
| 4 | Rain forest | Red-orange | 48 (2) | 38 (4) | 35 (3) |
| 5 | Rain forest | Red | 27 (2) | 24 (4) | 28 (2) |
| 6 | Rain forest | Orange | 51 (2) | 46 (4) | 48 (1) |
| 7 | Rain forest | Orange-green | 60 (4) | 48 (5) | 41 (2) |
| 8 | Rain forest | Orange-green | 24 (2) | 22 (2) | 33 (1) |
| 9 | Rain forest | Yellow-green | 35 (3) | 29 (3) | 30 (2) |
| 10 | Rain forest | Yellow-green | 50 (6) | 44 (4) | 36 (2) |
| 11 | Rain forest | Red-green | 43 (4) | 34 (4) | 40 (3) |
| 12 | Rain forest | Orange-green | 33 (5) | 26 (3) | 34 (2) |
| 13 | Andes | Red | 19 (2) | 19 (2) | 29 (2) |
| 14 | Andes | Yellow-green | 33 (4) | 31 (4) | 31 (3) |
| 15 | Andes | Orange-green | 19 (2) | 19 (1) | 26 (2) |
| 16 | Andes | Yellow | 16 (2) | 14 (3) | 20 (3) |
| 17 | Andes | Yellow-green | 15 (1) | 14 (3) | 25 (3) |
| Mean | | | 34 (14) | 29 (11) | 34 (8) |

[a] The first 12 samples were bought in the villages of Sabaleta (samples 1, 2, 4, 5, 8–12) and Raposo (samples 3, 6, 7), near Buenaventura in the rain forest of the Colombian Pacific coast and the others in the Andean villages of Mandiva (samples 13, 14) and Palmar (samples 15–17), near Santander de Quilichao, Cauca (Occidental Cordillera).

[b] Mean (standard deviation) of a whole raceme (20–40 fruits).

composition and the nutritive value among cultivated varieties.

## MATERIAL AND METHODS

### Samples

Seventeen samples of cultivated peach palms were bought in two villages of the Pacific coast rain forest and two of the Andes of Colombia, in order to cover all the phenotypes encountered in the region. A whole raceme was bought and the fruits were evaluated for their colour, weight, volume and length (Table 1).

### Analyses

The samples were cut and the seeds removed. The mesocarp and exocarp were then freeze-dried and ground to pass through a 1-mm-mesh screen. The flour was analyzed for its content in ash (furnace at 550 °C for 8 h), nitrogen (Kjeldahl method), oil (ether extract by the Soxhlet system) as described by the AOAC,[8] neutral and detergent fibres[9] and starch.[10] A different technique of starch analysis was used for the rat faeces.[11] The minerals were determined by atomic absorption spectroscopy after mineralization in a furnace and recovery in a $HNO_3/HClO_4$ (2/1) solution, by means of a Perkin-Elmer Zeeman AAS 800 (Perkin-Elmer, Wellesley, MA, USA). Chlorine was determined by titrimetry and phosphorus by colorimetry. The total and reducing sugars were analyzed by colorimetry after extraction with ethanol[12] and the amino acids by ion exchange chromatography,[13] using a Biochrome 20 analyser (Pharmacia Biotech Ltd, Cambridge, UK). Methionine and cysteine were determined by the same method after oxidation with performic acid before hydrolysis. Tryptophan was also determined in this way but after an alkaline hydrolysis using 4N BaOH. The amylopectin and amylose proportions in purified starch were determined by the iodine method.[14] Isolated starch was obtained after maceration of the mesocarp for one night in water, followed by filtration on a cheese-cloth and decantation of starch in suspension in water. Crude energy was determined using a Parr 1342 calorimeter (Parr Instruments, Moline, IL, USA). The analysis of minerals and amino acids were limited to six and two samples, respectively.

### Total tract digestibility in rats

The total tract digestibility of the main nutrients of four phenotypes of peach palm was determined in rats. The selected samples were Nos 1 (yellow), 3 (orange-green), 7 (red-green) and 9 (yellow-green). Six diets were formulated: one control, one N-free diet and four diets containing 350 g kg$^{-1}$ peach palm and 650 g kg$^{-1}$ of a control diet. The control diet contained: 650 g maize kg$^{-1}$ DM and, in g kg$^{-1}$, 70 g soybean meal, 100 g sucrose, 60 g oil (soybean: sunflower 50:50), 60 g ground rice hulls and 60 g minerals together with vitamins (43% $CaCO_3$, 25% $Ca_2HPO_4$, 16% NaCl and 17% of a commercial premix of trace elements and vitamins). The N-free diet was composed of 700 g starch kg$^{-1}$ DM and, in g kg$^{-1}$, 100 g sucrose, 80 g ground rice hulls, 60 g minerals and vitamins (see above) and 60 g oil.

Ten Sprague–Dawley rats weighing on average 150 g (±12 g) were placed in a metabolic cage

(Tecniplast, Buguggiate, Italy) and received, daily, 20 g of one of the five diets (control and four peach palm-based diets), presented in ground form. The experimental design was a completely randomized scheme: the rats were randomly allocated to one of the diets (two rats per diet). After a 5-day adaptation period to the diet, the faeces were collected completely for 8 days. They were weighed and immediately kept at −18 °C. The diets were then randomly permuted and another period of collection was performed for 8 days. Afterwards, six rats were randomly selected and fed with an N-free diet for 6 days. The intake was measured and the faeces were collected, weighed and analyzed for DM and N content. After the experiment, the faeces were freeze-dried, ground to pass through a 1-mm-mesh screen and analyzed, together with the diet, for their ash, nitrogen, starch and energy content.

The extent of digestibility of DM, the crude protein and the energy were calculated by difference between the amount of matter ingested and excreted. The results of endogenous N excretion obtained by the N-free diet technique were expressed per kg DM intake.

## Growth trial in rats

A growth experiment was performed in order to study the effect of peach palm intake level on rat growth. Five diets were formulated: one control and 4 diets containing 200, 400, 600 and 800 g peach palm $\mathrm{kg^{-1}}$. The diets were formulated in order to be isoproteic and isoenergetic (Table 2).

The rats were placed in individual stainless steel cages and had permanent access to water. The experimental design was a totally randomized scheme: the rats were randomly allocated to one of the diets and five rats were used per diet. They had an initial weight of 78 ± 9 g on average and received initially 10 g $\mathrm{day^{-1}}$. Thereafter, the quantity was adapted according to the rat's appetite. Every day, the refusals were taken and weighed. The rats were weighed every week and the experiment lasted 28 days.

## Calculations and statistical analyses

The different parameters were calculated as follows:

*Total tract digestibility experiment*

$$\text{Apparent N digestibility} = (\mathrm{Ni} - \mathrm{fN})/\mathrm{Ni}$$

$$\text{True N digestibility} = [\mathrm{Ni} - (\mathrm{fN} - \mathrm{efN})]/\mathrm{Ni}$$

where Ni is the nitrogen intake, fN the faecal nitrogen and efN the endogenous faecal N.

*Growth trial in rats*

$$\text{Feed efficiency} = \mathrm{BMG}/\mathrm{Fi}$$

$$\text{Protein efficiency ratio (PER)} = \mathrm{BMG}/\mathrm{Ni}$$

where BMG is the body mass gain (g), Fi the feed intake (g) and Ni the nitrogen intake (g)

*Protein quality*

$$\mathrm{PDCAAS}(\%) = [\mathrm{AAC} \times \mathrm{D}]/\mathrm{AAP}$$

where PDCAAS means protein digestibility-corrected amino acid score, AAC is the amino acid (AA) content in food protein (% crude protein), D is the true digestibility and AAP is the amino acid content in the 1985 FAO/WHO/UNU requirement pattern for 2–5-year-old children[16] (% protein).

Values reported are means ± SEM (standard-error of the means) or SD (standard deviation). Significant

**Table 2.** Composition of the diets used for the growth experiment (g $\mathrm{kg^{-1}}$ DM)

| | | Peach palm diets | | | |
|---|---|---|---|---|---|
| Diets | Control | 200 g $\mathrm{kg^{-1}}$ | 400 g $\mathrm{kg^{-1}}$ | 600 g $\mathrm{kg^{-1}}$ | 800 g $\mathrm{kg^{-1}}$ |
| *Composition* | | | | | |
| Peach palm | — | 200 | 400 | 600 | 800 |
| Casein + methionine[a] | 115 | 104 | 92 | 81 | 70 |
| Maize starch | 557 | 417 | 279 | 140 | — |
| Oil[b] | 107 | 80 | 53 | 27 | — |
| Sucrose | 80 | 80 | 80 | 80 | 80 |
| Minerals/vitamins[c] | 50 | 50 | 50 | 50 | 50 |
| Ground rice hulls | 91 | 69 | 46 | 22 | — |
| *Analysis* | | | | | |
| Protein | 95 | 97 | 98 | 100 | 101 |
| Starch | 462 | 489 | 518 | 546 | 573 |
| Oil | 107 | 103 | 99 | 95 | 91 |
| Neutral detergent fibre | 74 | 64 | 53 | 37 | 31 |
| Digestible energy[d] (kcal $\mathrm{kg^{-1}}$ DM) | 3520 | 3560 | 3600 | 3650 | 3690 |

[a] Casein (C7078, Sigma, St Louis, USA) +3 g methionine $\mathrm{kg^{-1}}$; essential amino acid profile, including correction for methionine (g $\mathrm{kg^{-1}}$ protein, INRA[17]: 41 Arg, 31 His, 61 Ile, 92 Leu, 82 Lys, 31 Met, 34 Met + Cys, 49 Thr, 17 Trp, 72 Val).

[b] Oil (50:50, soybean: sunflower).

[c] Minerals: 43% $\mathrm{CaCO_3}$, 25% $\mathrm{Ca_2HPO_4}$, 16% NaCl, 17% premix with vitamins and oligo-elements.

[d] Digestible energy calculated with the average digestible energy of peach palm (see digestibility trial) and that reported for the other ingredients in pigs by INRA.[17]

differences were determined by analysis of variance followed by comparisons using the Newman–Keuls multiple-range test. $p < 0.05$ was considered as significant limit. The correlation between oil and starch content was calculated by using two-tailed non-parametric rank correlation (Spearman) by means of the InStat statistical software (GraphPad, San Diego, CA, USA).

## RESULTS

The composition of the 17 peach palm samples, detailed in Table 3, is in agreement with many data of literature.[2,7,15] It is mainly composed of starch (>700 g kg$^{-1}$ DM, on average) and oil (60–180 g kg$^{-1}$ DM). However, it is poor in protein, fibre, sugars and minerals. There is a highly significant ($p < 0.001$) and negative correlation between the oil and starch contents (Fig 2). The content in most of the macro- and micro-elements is low, with the exception of potassium and iron, respectively (Table 4). The proteins are low in methionine and tryptophan, but the lack in methionine is compensated by good cysteine content (Table 5). The sum of the amino acids (AAs) explains only 71–75% of the total crude protein content. The lowest protein digestibility corrected AA score (PDCAAS) value was obtained for tryptophan, making this AA the one most limiting for protein retention. However, most of the essential AAs, with the exception of the S-containing ones and of valine, are also below the requirements of children of 2–5 years, taken as a reference by the FAO/WHO/UNU[16] to evaluate the quality of a protein.

The digestibility coefficients of the diets containing peach palm and those of the peach palm alone, calculated by difference, are detailed in Table 6. Significant differences ($p < 0.05$) among treatments were observed only for starch. The high DM and energy digestibility coefficients are due to the high starch and oil contents. The apparent protein digestibility coefficients were low. This is ascribed to the low protein content of the diets, whereas the true values were high and comparable with those obtained for the other components. No significant difference was observed for the digestible energy content of the peach palms ($p > 0.05$).

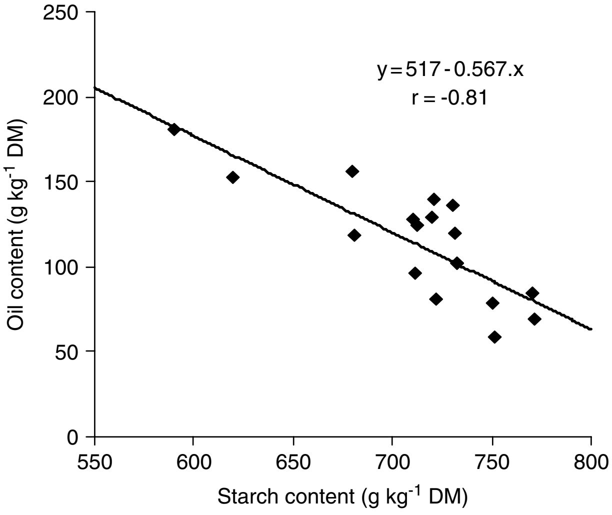

**Figure 2.** Relationship between the starch and oil contents of peach palm fruits.

**Table 3.** Dry matter (g kg$^{-1}$), crude energy (kcal kg$^{-1}$ DM) and chemical composition of 17 Colombian peach palms (g kg$^{-1}$ DM)

| No | Dry matter | Crude protein | Oil | Crude fibre | NDF[a] | ADF[b] | Starch[c] | Total sugars | Reducing sugars | Ash | Crude energy |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 438 | 55 | 129 | 18 | 35 | 19 | 720 | 23 | 14 | 17 | 4.405 |
| 2 | 420 | 49 | 69 | 11 | 11 | 8 | 770 | 8 | 6 | 16 | 4.527 |
| 3 | 383 | 60 | 69 | 9 | 22 | 14 | 780 | 15 | 8 | 16 | 4.228 |
| 4 | 429 | 43 | 140 | 15 | 32 | 16 | 750 | 9 | 6 | 15 | 4.397 |
| 5 | 438 | 47 | 120 | 16 | 22 | 9 | 730 | 14 | 11 | 15 | 4.347 |
| 6 | 397 | 51 | 124 | 20 | 41 | 19 | 710 | 18 | 17 | 17 | 4.506 |
| 7 | 364 | 57 | 156 | 25 | 49 | 22 | 680 | 16 | 8 | 18 | 4.464 |
| 8 | 381 | 60 | 79 | 17 | 35 | 18 | 750 | 15 | 9 | 20 | 4.572 |
| 9 | 457 | 42 | 128 | 16 | 30 | 12 | 710 | 25 | 15 | 18 | 4.276 |
| 10 | 455 | 43 | 84 | 12 | 27 | 10 | 770 | 24 | 11 | 17 | 4.266 |
| 11 | 501 | 52 | 119 | 19 | 38 | 17 | 680 | 44 | 17 | 19 | 4.263 |
| 12 | 471 | 52 | 96 | 18 | 33 | 11 | 710 | 20 | 12 | 18 | 4.260 |
| 13 | 321 | 73 | 181 | 41 | 78 | 44 | 590 | 23 | 14 | 28 | 4.705 |
| 14 | 461 | 54 | 59 | 19 | 37 | 12 | 750 | 20 | 17 | 16 | 4.700 |
| 15 | 297 | 93 | 152 | 32 | 57 | 31 | 620 | 31 | 21 | 12 | 4.470 |
| 16 | 462 | 58 | 81 | 27 | 71 | 24 | 720 | 33 | 29 | 14 | 4.402 |
| 17 | 302 | 30 | 102 | 21 | 43 | 21 | 730 | 25 | 21 | 24 | 4.332 |
| Mean | 410 | 54 | 114 | 20 | 39 | 18 | 716 | 21 | 14 | 18 | 4.419 |
| SD | 61 | 14 | 35 | 08 | 17 | 9 | 51 | 9 | 6 | 4 | 167 |

[a] NDF: neutral detergent fibre.

[b] ADF: acid detergent fibre.

[c] An analysis of purified starch revealed that it contains, on average, 95% amylopectin and 5% amylose.

**Table 4.** Mineral contents of six samples of Colombian peach palms (g or mg kg$^{-1}$ DM)

| | g kg$^{-1}$ DM | | | | | | | mg kg$^{-1}$ DM | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | Ca | P | Mg | K | Na | S | Cl | Fe | Cu | Zn | Mn | Co | Se |
| 2 | 1.0 | 0.8 | 0.8 | 9.3 | 0.2 | 0.6 | 1.2 | 59 | 7 | 18 | 9 | 0.1 | 0.1 |
| 5 | 1.3 | 1.2 | 0.5 | 7.7 | 0.3 | 0.6 | 0.9 | 39 | 3 | 7 | 4 | 0.1 | <0.1 |
| 13 | 0.8 | 0.7 | 0.7 | 12.4 | 0.4 | 1.8 | 0.6 | 51 | 5 | 12 | 7 | 0.1 | 0.1 |
| 14 | 0.9 | 0.6 | 0.6 | 7.5 | 0.3 | 0.8 | 0.4 | 63 | 4 | 7 | 5 | 0.1 | <0.1 |
| 15 | 0.9 | 0.7 | 0.6 | 6.6 | 0.2 | 0.9 | 0.7 | 24 | 3 | 9 | 3 | <0.1 | 0.2 |
| 16 | 0.9 | 0.6 | 0.6 | 5.9 | 0.3 | 1.1 | 0.9 | 29 | 3 | 8 | 4 | <0.1 | <0.1 |
| Mean | 1.0 | 0.8 | 0.6 | 8.2 | 0.3 | 1.0 | 0.8 | 44 | 4 | 10 | 5 | 0.1 | 0.1 |
| SD | 0.2 | 0.2 | 0.1 | 2.3 | 0.1 | 0.5 | 0.3 | 16 | 2 | 4 | 2 | — | — |

**Table 5.** Amino acid content (g kg$^{-1}$ DM) and profile (g kg$^{-1}$ protein) of two peach palms and protein digestibility-corrected amino acid score (PDCAAS) of peach palm protein (%)

| | Amino acid g kg$^{-1}$ DM | | Amino acid g kg$^{-1}$ protein | | |
|---|---|---|---|---|---|
| Peach palm | Yellow[a] | Red[a] | Yellow | Red | PDCAAS (%) |
| Essential | | | | | |
| Arginine | 3.1 | 2.8 | 58 | 51 | — |
| Histidine | 1.4 | 1.0 | 19 | 18 | — |
| Isoleucine | 1.8 | 1.5 | 25 | 28 | 90 |
| Leucine | 3.9 | 3.0 | 54 | 55 | 78 |
| Lysine | 3.7 | 2.6 | 50 | 47 | 79 |
| Methionine | 0.9 | 0.7 | 12 | 13 | — |
| Methionine–cysteine | 2.4 | 1.6 | 32 | 30 | 117 |
| Phenylalanine | 2.0 | 1.5 | 27 | 27 | — |
| Phenylalanine–tyrosine | 3.4 | 2.7 | 46 | 49 | 71 |
| Threonine | 2.9 | 2.1 | 39 | 38 | 99 |
| Tryptophan | 0.5 | 0.5 | 7 | 7 | 60 |
| Valine | 2.7 | 2.1 | 37 | 39 | 103 |
| Non-essential | | | | | |
| Alanine | 5.0 | 3.2 | 69 | 59 | — |
| Aspartic acid | 6.6 | 4.2 | 90 | 77 | — |
| Cysteine | 1.5 | 0.9 | 20 | 17 | — |
| Glutamic acid | 6.1 | 4.4 | 83 | 79 | — |
| Glycine | 3.4 | 2.5 | 46 | 45 | — |
| Proline | 2.6 | 2.0 | 36 | 36 | — |
| Serine | 4.2 | 3.0 | 58 | 55 | — |
| Tyrosine | 1.4 | 1.2 | 19 | 22 | — |
| Total | 53.7 | 39.2 | 749 | 713 | — |
| Nitrogen | 11.7 | 8.8 | — | — | — |

[a] Samples Nos 1 (yellow) and 13 (red).

The results of the growth experiment are detailed in both Table 7 and Fig 3. The lower the peach palm content in the diet, the higher the rat growth rate. This is partly explained by a significantly ($p < 0.05$) lower feed intake for the rats receiving peach palm. The results of PER (g gain g$^{-1}$ ingested protein) also express a lower quality of the peach palm protein, compared with that of casein. The results above show that the low quality is due to a poor amino acid profile rather than to digestibility problems. The evolution of the rat weight over time (Fig 3) shows that the animals fed with high amounts of peach palm were mainly affected during the first week of the experiment but that, afterwards, their growth was more comparable with that of rats fed with lower amounts. This probably reflects an adaptation to the taste.

## DISCUSSION

Many authors[2,7,15] report wide variations in the composition of peach palm. However, the widest variations were observed in wild varieties or species. In the present case, such variation was less and limited to starch and oil content (Table 3). No correlation was observed between phenotypic characters such as fruit size and colour. This is inconsistent with the local belief that small, red fruits are richer in oil. Though the number of samples was not sufficient here to draw definitive conclusions, no clear relationship between colour and composition has been observed.

In contrast, a strong and negative correlation was found between starch and oil (Fig 2). Roughly, a decrease in 1 g of starch is compensated by an increase of 0.57 g of oil. This can slightly affect the energy value of peach palm. Using the digestible energy values provided by INRA[17] for vegetable oil and starch, it can be calculated that the energy value of the sample with the lowest oil content here (60 g kg$^{-1}$) will be 153 kcal lower than that of the sample with the highest oil level (180 g kg$^{-1}$). High oil content is of interest for other purposes such as oil extraction or human nutrition, since people prefer such peach palms. Oil is mainly composed of palmitic acid (240–420 g kg$^{-1}$ oil) and oleic acid (430–610 g kg$^{-1}$ oil) but in variable proportions.[2,7] However, if starch extraction is preferred, the presence of oil can affect the process. Peach palm starch is very attractive for the agro-industry since it is composed of 95% of amylopectin (see footnote to Table 3).

The protein content is disappointing from a nutritional point of view, since the average content did not exceed 54 g kg$^{-1}$ DM (Table 2). Neither is the quality good. The AAs explain only three-quarters of total N. According to Milton and Dintzis,[18] up to 20% of the total N of the tropical fruits of the rain forest can be non-proteinaceous. The 6.25 nitrogen-to-protein conversion factor is, therefore, not valid and these authors suggest a conversion factor as low as 4.4,

**Table 6.** Digestibility of the experimental diets and of the peach palm alone (%) and digestible protein (g kg$^{-1}$ DM) and energy (kcal kg$^{-1}$ DM) contents

| | Dry matter (%) | Energy (%) | Starch (%) | Nitrogen Apparent (%) | Nitrogen True (%) | Digestible protein (g kg$^{-1}$ DM) | Digestible energy (kcal kg$^{-1}$ DM) |
|---|---|---|---|---|---|---|---|
| *Experimental diet* | | | | | | | |
| Control | 80.9$^{a}$ | 84.8 | 95.8$^{a}$ | 73.2 | 84.8$^{a}$ | | |
| Peach palm 1 | 84.3$^{b}$ | 84.6 | 94.4$^{b}$ | 75.2 | 88.8$^{b}$ | | |
| Peach palm 3 | 84.7$^{b}$ | 85.4 | 96.4$^{a}$ | 74.8 | 88.0$^{b}$ | | |
| Peach palm 7 | 83.4$^{b}$ | 84.0 | 96.5$^{a}$ | 73.6 | 86.6$^{ab}$ | | |
| Peach palm 9 | 84.5$^{b}$ | 85.5 | 95.8$^{a}$ | 76.0 | 89.7$^{b}$ | | |
| SEM | 0.4$^{**}$ | 0.2$^{ns}$ | 0.2$^{*}$ | 0.4$^{ns}$ | 0.5$^{*}$ | | |
| *Peach palm* | | | | | | | |
| Peach palm 1 | 91.4 | 86.5 | 91.9$^{a}$ | 77.8 | 96.1$^{a}$ | 49$^{a}$ | 3.707 |
| Peach palm 3 | 92.7 | 88.7 | 97.5$^{b}$ | 76.3 | 93.9$^{ab}$ | 53$^{bc}$ | 3.657 |
| Peach palm 7 | 89.1 | 84.9 | 97.7$^{b}$ | 72.9 | 89.9$^{b}$ | 52$^{b}$ | 3.687 |
| Peach palm 9 | 92.1 | 89.0 | 95.9$^{b}$ | 79.9 | 98.7$^{a}$ | 51$^{ab}$ | 3.711 |
| SEM | 0.2$^{ns}$ | 0.9$^{ns}$ | 0.6$^{*}$ | 1.9$^{ns}$ | 1.4$^{*}$ | 0.4$^{*}$ | 33$^{ns}$ |

$^{a,b}$ means with different superscripts differ significantly (ns: non significant; *: $p < 0.05$; **: $p < 0.01$); SEM: standard error of the mean.

**Table 7.** Feed intake, growth, protein efficiency ratio and feed conversion in rats fed a diet containing 0 to 800 g peach palm kg$^{-1}$ diet for one month

| | Control | Peach palm 200 g kg$^{-1}$ | Peach palm 400 g kg$^{-1}$ | Peach palm 600 g kg$^{-1}$ | Peach palm 800 g kg$^{-1}$ | SEM |
|---|---|---|---|---|---|---|
| Feed intake (g day$^{-1}$) | 12.0$^{a}$ | 10.1$^{b}$ | 9.9$^{b}$ | 9.2$^{bc}$ | 8.1$^{c}$ | 0.3$^{*}$ |
| Growth (g day$^{-1}$) | 3.46$^{a}$ | 2.89$^{ab}$ | 2.30$^{bc}$ | 1.87$^{cd}$ | 1.41$^{d}$ | 0.16$^{*}$ |
| PER | 4.91$^{a}$ | 2.94$^{b}$ | 2.36$^{c}$ | 2.03$^{cd}$ | 1.69$^{d}$ | 0.12$^{*}$ |
| Feed conversion | 3.49$^{a}$ | 3.49$^{a}$ | 4.31$^{a}$ | 4.97$^{a}$ | 6.17$^{b}$ | 0.25$^{*}$ |

PER: protein efficiency ratio, g gain g$^{-1}$ protein intake.
Feed conversion: g gain g$^{-1}$ DM intake.
$^{a,b,c,d}$ Means with different superscripts in the same row differ significantly (*: $p < 0.05$); SEM: standard error of the mean.

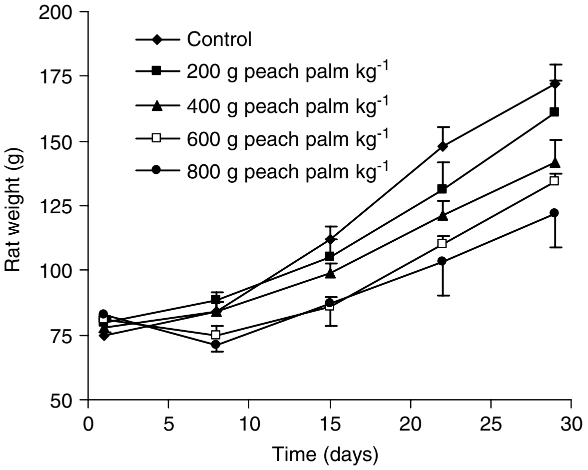

**Figure 3.** Evolution over time of the rat weight fed increasing levels of peach palm, in comparison with a control diet based on casein supplemented with methionine.

which reduces still more the protein content of peach palm in the fruit.

The PDCAAS does not exceed 60%, with tryptophan the most limiting essential AA (Table 5). This value, broadly used to evaluate the nutritional quality of a protein in human nutrition, corresponds to the ratio between the content of the first limiting AA, corrected for its true digestibility, and the requirements of 2–5-year-old children (expressed in % protein). It means that a child fed only with this protein source, would retain 60% of the protein, the rest being catabolized. This value is still better than that of cereals such as maize or wheat (0.42).[19] It is also comparable with values obtained for other unconventional tropical crop seeds (37–88%).[20] However, in the present case, most of the other essential AAs do not reach the level of the reference protein either, since they present a PDCAAS <100. This means that the peach palm must be complemented with well-balanced proteins such as milk, meat or soybean meal. If these sources are available, the low protein content is no longer a problem since it will not be necessary to find a protein source that counter-balances the AA deficiencies of peach palm.

Peach palm is also very poor in minerals (Table 4). Its mineral profile is comparable with that of cereals such as maize or wheat.[17] Even high intakes would not cover the requirements of any element, in humans or in animals.[17,21]

In contrast, peach palm is very well digested (Table 5). This is no wonder since it is very poor in fibres (Table 3). Cell walls are thin and do not impair the release of the starch granules and of oil. Moreover, starch is mainly composed of amylopectin, its branched-chain form, which is more easily accessible to digestive enzymes and does not form crystals. Furthermore, the digestibility of oil is always very high. The apparent protein digestibility was lower but this is ascribed to the low protein content of peach palm. The low dietary protein supply increases the relative proportion of endogenous N in the faeces, coming from unreabsorbed digestive secretions, and lowers the apparent digestibility. The high true digestibility values confirm this hypothesis.

The digestible energy content of the peach palm (3.690 kcal DE $kg^{-1}$ DM on average) was high and slightly lower than that of maize or wheat in pigs, for example (respectively 3.950 and 3.850 kcal DE $kg^{-1}$ DM).[17] The truly digestible protein content (51 g $kg^{-1}$ DM), on the contrary, was lower than any cereal and makes peach palm more comparable to tubers such as cassava or potatoes (from 30 to 100 g $kg^{-1}$ DM).[17]

Because of the low protein content, it was not possible to carry out a growth experiment in rats in which peach palm would be the only protein source. Therefore, the peach palm protein represented, in the diets containing from 0 to 800 g peach palm $kg^{-1}$, respectively: 0, 11, 22, 33 and 44% of the total protein content.

Part of the decrease in rat growth rate (Table 7) can be ascribed to a lower DM intake. A similar decrease has been observed in rats fed diets containing 0–800 g peach palm $kg^{-1}$ diet at the expense of sorghum,[4] although the intake decrease in chickens and hens receiving diets containing 0–600 g peach palm $kg^{-1}$ was very limited.[22] Part of the explanation could lie in the poor tryptophan availability of the proteins, since a lack of this AA in the diet significantly affects appetite.[23] Authors also evoke the presence of various antinutritional factors, such as trypsin inhibitors, lectins or even Ca oxalates.[4–6,24] However, their presence is quite limited and their destruction by heat treatment has resulted in a very limited improvement of dietary intake by the animals.[5,6,22] Mora-Kopper *et al*[25] mention possible problems of rancidness of the oil, due to the activity of endogenous lipases, but such a problem was not obvious here. However, a bitter taste of peach palm is often evoked by people eating this fruit for the first time. In a previous experiment, not reported, we fed rats with a green peach palm, almost devoid of oil, and the rats refused to eat it. The present authors have also tested the fruit and everybody agreed that the taste was very bitter. As far as we know, no information is available on the origin of this bitterness. It exists in some varieties and could limit the consumption of peach palm by humans or animals. The observation of the evolution of the growth rate of the rats receiving 600 and 800 g peach palm $kg^{-1}$ during the growing period shows that, during the first week, the rats lost weight and then recovered (Fig 3). This probably illustrates the necessity of a longer adaptation period to the peach palm taste. Finally, it is worth mentioning that no significant difference ($p > 0.05$) in growth rates was observed between rats fed the diets containing 200, 400 and 600 g peach palm $kg^{-1}$. This suggests that, with an appropriate protein supplementation, better results could be expected at high peach palm intakes.

The data of protein efficiency ratio and conversion index also explain the decrease in rat growth rate when the peach palm content in the diet increases (Table 7). This is mainly attributable to the poor quality of the protein (see AA profile of peach palm in Table 5 and of casein in the footnote of Table 2). This was confirmed by Murillo *et al*[22] in chickens and laying hens. The growth or production of these animals decreased significantly only when the proportion of peach palm in the diet exceeded 49 and 34%, respectively.

## CONCLUSION

Peach palm is a valuable energy source for humans and animals and it can be incorporated at high levels in the diet without affecting the consumer's health although its nutritional interest is limited by its low protein and mineral contents. The variability in composition among cultivated varieties is quite limited and mostly dependent on the cultivation conditions.

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