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Evaluation of *Pithecellobium dulce* (Camachile) fruit and its aril powder

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Abstract
Pithecellobium dulce or camachile is an underutilized crop due to lack of awareness, very few investigations have been done on this. Keeping this in view, present research is undertaken to evaluate the ripe, raw arils and develop a fruit powder. Nutritionally no much difference is recorded between the ripe and raw arils of the fruit, the former having a slightly higher content of protein and reducing sugars i.e. 12.14% and 4.222% respectively. Raw arils are determined to be good source of ascorbic acid 385 mg/100 g. To prevent browning of the arils during the drying process, the arils are subjected to blanching and 0.5% KMS, 1% KMS and 1% ascorbic acid pretreatments, among which 0.5% KMS treatment is produced a visually preferable colour after drying and comminution.

Keywords: Camachile, underutilized, fruit powder, multigrain pasta

Introduction
India, a developing country and being the second most populous country in the world, the nation holds responsibility of feeding its 130-crore people. However, with increasing population pressure and improving standards of living human survivorship has become one of the biggest challenges for mankind with a threat for potential food and nutritional scarcity due to the apathetic exploitation of resources causing its depletion. This arises the need to search for alternatives, thus exploring the unexplored and utilising the underutilised plant species. Manila Tamarind is one such fruit A large, nearly evergreen tree that grows up to 20 m or more in height,

Manila tamarind has a broad crown (to 30 m across) and a short bole (to 1 m thick). At the base of each leaf is normally found a pair of short, sharp spines, though some specimens are spineless (NAS, 1980a) [13]. Often planted for living fence or thorny hedge, eventually nearly impenetrable, camachile furnishes food, forage, and firewood, while fixing a little nitrogen. In India it is mostly found in states of Andhra Pradesh, Rajasthan, West Bengal, and Delhi. The tree bears coiled fruits from end of the April till June. The fruit is a pod having sweet and slightly astringent white and red arils depending upon the tree covering black seeds. According to Kaushik and Varsha (2018) [9] study of the extract of the fruit showed that the fruit had several nutraceutical properties such as antibacterial, anti-oxidant, anti-inflammatory, hepatoprotective, antiulcer and anti-diabetic properties. The fruit is exceptionally perishable leading to huge waste, since there is no preservation or value addition. These days a great number of desired properties are being incorporated today in various products by the process of extrusion in the form of convenient foods. Pasta is one such product manufactured using the technique. However, the addition of other grains in the product enhance the nutritive value of the wheat flour along with the taste and health benefits. Nutrition and taste must go hand in hand if one is to lead a healthy lifestyle. Multigrain products do have many essentials that is required by the body for daily energy and fostering a sound, strong and fine fettle body. Taking all these points into consideration the following research was taken up with the objective of studying the physico-chemical properties of Camachile seed, aril and to develop Camachile fruit powder.

Material and Methods

The present study is conducted at Dr. NTR College of Food Science and Technology, Acharya N. G. Ranga Agricultural University, Bapatla, Guntur Dist., Andhra Pradesh.

Camachile Fruit: The fresh raw and matured camachile fruits used for the study are obtained by directly plucking the fruits from the trees that grow in the area i.e. Bapatla, Guntur Dist., Andhra Pradesh. Fresh, healthy, raw, ripe and defect free fruits are then sorted out manually and selected for the study. The fruits are cleaned (removal of leaves, dirt etc.), peel and seeds removed and the arils are packed in LDPE pouches, sealed and stored at -18 + 5 °C.

Physical Properties of the Fruit: Physical properties such as dimensions, volume, and fruit density are determined for the manila tamarind. Fruit Size is determined by digital Vernier calliper having a least count of 0.01 mm. Fruit volume is determined by using water displacement method and the fruit density of the camachile is obtained by the following equation (Mohsenin, 1978) [12]:

Chemical Properties of the fruit: The percentage of total soluble solids is determined by using digital refractometer and expressed as °Brix, Titratable Acidity is determined by AOAC Official Method 2000 [1], Ascorbic acid is estimated by the method of Sadasivam and Balasubramanian, 1987 [18], Moisture content is estimated using air oven drying method by placing about 2-5 g of sample for 24 h in a hot air oven (Model KOMA 3) maintained at 103 + 1°C (FSSAI, 2012) [5], The fat content of the sample is determined by semi-continuous soxhlet method using soxhlet apparatus (Model SCS 4), Crude protein of the sample is estimated using micro-kjeldahl method. The ash content is determined using AOAC Official Method 2000 [1], Crude fibre is estimated using AOAC Official Method 2005 [2], the carbohydrate content of the sample on dry weight basis is calculated by difference method (Jain and Mogra, 2006) [8], the amount of total phenols is estimated by the method proposed by Mallick and Singh (1980) [11], Reducing sugars in the fruit is determined by AOAC Official Method 920.183, Anthocyanin content is estimated using AOAC Official Method 2005 [2]. 02 for the ripe fruit arils.

Procedure for obtaining fruit powder: The fruits received locally are initially manually separated for raw and ripe fruits based on visual observation and then the peel and seeds are manually separated. The arils obtained are initially dried in a solar dryer for 18 hours until consecutive three constant readings are obtained. Browning of the fruit arils is observed. Thus, to prevent browning of the fruit, the fruit arils are subjected to pre-treatments. Initially blanching is carried out for 5 min at 85°C and then the blanched arils are given 0.5% potassium bisulphate (KMS), 1.0% KMS and 1% ascorbic acid treatment. These arils are now subjected to tray drying at 75°C for 4 hours. The 0.5% KMS treatment gives a preferable colour visually, thus is best acceptable and hence is subjected to sieve analysis which gives the particle size of fruit powder to be 300µ. The accepted treatment is followed for obtaining larger amount of fruit powder and the developed fine camachile fruit powder is packed in LDPE pouch packs and stored at ambient temperature.

Functional and Flow ability Properties of Fruit Powder

Bulk density: The bulk density (BD) of the fruit powder is determined using the method described by Okezie and Bello (1988) [15]. A ten ml graduated cylinder, previously tarred is gently filled with ten gram of fruit powder sample. The volume is noted and bulk density is calculated as Weight of sample (g)/Volume of sample (mL).

Tapped Density

The tapped density of the sample is measured by putting 2.5 gm of powder mixture in a 10ml graduated measuring glass cylinder and the tapped volume is measured after the sample was gently dropped 100 times onto a rubber mat from a height of 15 cm (Ozdikicierler *et al*., 2014) [16]. Then the tapped density is calculated by dividing the weight of powder by the tapped volume. Tapped density is calculated as Weight of the sample/ Volume of the sample after tapping

Compressibility index or carr's index: The compressibility index (CI), also known as Carr's index or Carr's Compressibility Index, is an indication of the compressibility of a powder. A Compressibility index greater than 25 is considered to be an indication of poor flowability, and below 15, of good flowability. The tapped and bulk densities are used in calculating the compressibility index (CI) as follows (Zhou *et al*., 2008) [22]. Calculated as Tapped density – Bulk Density/Bulk density ×100.

Hausner ratio: The Hausner ratio (HR, dimensionless) is a number that is correlated to the flowability of a powder or granular material. A Hausner ratio greater than 1.25 is considered to be an indication of poor flowability. It is the ratio of tapped to loose bulk density (Zhou *et al*., 2008) [22]

Water retention/absorption capacity: Water retention capacity is determined by the method followed by the method followed by Fuentes-Alventosa *et al.* 2009 [6]. 1 g of sample is hydrated in 30 mL of distilled water and allowed to stand at ambient temperature for 10 min, then centrifuged for 15 min at 2000 rpm where the supernatant is discarded and the wet sediment weight is noted as calculated as Wet weight (g) – Dry weight (g) / Dry Weight (g) × 100.

Water holding capacity: The water holding capacity is determined by the method followed by Robertson *et al.*, 2001. 1 g of sample is hydrated in 30 mL of distilled water at room temperature (30°C). After equilibration (for 18 h), sample is centrifuged at 3000 rpm for 20 min and supernatant is removed. The weight of the residue is recorded both prior to drying at 105°C and after drying until constant weight is obtained. Water holding capacity is calculated as the amount of water retained by the sample (g/g dry weight) as Residue fresh weight (g) – Residue dried weight (g) Residue dried weight (g).

Swelling capacity: Swelling capacity is determined by the method of Robertson *et al*., 2000. 0.1 g of sample is hydrated in 10 mL of distilled water in a calibrated cylinder (15cm diameter) at ambient temperature (~30°C). After equilibration of 18 h, the bed volume is recorded and recognized as volume of original substrate dry weight. Calculated as Original sample dried weight (g) / Volume occupied by sample (mL)

Oil absorption capacity: The oil absorption capacity is determined by the method followed by Sosulski *et al.,* (1976). 1 g of sample is mixed with 10 mL of oil and allowed to stand at ambient temperature (30 + 2°C) for 30 min, then centrifuged for 30 min at 3000 rpm. Wet weight is noted.

Calculation is Weight of the wet sample-Weight of the dry sample/ Weight of the dry sample×100

Foam capacity: The foam capacity (FC) is determined as described by Narayana and Narsinga Rao, 1982 [14] with slight modification. The 1.0 g flour sample is added to 50 mL distilled water at 30 ± 2°C in a graduated cylinder. The suspension is mixed and shaken for 5 min to foam. The volume of foam at 30 s after whipping is expressed as foam capacity using the formula: Volume of foam AW – Volume of foam BW / Volume of foam BW × 100. Where, AW = after whipping

BW = before whipping

Least gelation capacity: The least gelation concentration (LGC) is evaluated using a method of Coffman and Garcia, 1977. The flour dispersions of 2, 4, 6, 8, 10, and 20 % (w/v) prepared in 5 mL distilled water is heated at 90°C for 1 h in water bath. The contents are cooled under tap water and kept for 2 h at 10 ± 2 °C. The least gelation concentration is determined using the method given as that concentration when the sample from inverted tube does not slip.

Result and Discussions

Physical Properties of fruit: For any horticulture produce it is very important to determine its physical properties in order to design and develop harvesting and post harvesting technologies and equipment for e.g. sorting, grading, cleaning, transporting, packaging and production of different processed food. The volume and density of the fruit will help determine attainment of its maturity index, designing of storage structures and packaging materials, determining the purity of seeds etc. If not taken into consideration, the obtained outputs will lose its efficacy leading to greater degree of wastage. These criteria might give a broader picture for increasing the efficiency of the process and decrease unnecessary losses due to derisory applications. Hence, the physical properties of the manila tamarind are studied for a better outcome. A comparison of the raw and ripen fruit is done. Increase of length, breadth, and height of the fruit is observed with length, breadth and height expanding from 14.53 + 4.341 mm, 13.33 + 1.022 mm and 11.14 + 0.759 mm to 15.8 + 1.852 mm, 14.76 + 1.766 mm and 13.13 + 1.786 mm respectively since the cells of the fruit undergoes expansion as it matures. Thus, with increasing size, increase in volume and bulk density is also observed.

Table 1: Physical properties of raw and ripe Camachile

Physical Properties	Raw Fruit	Ripe Fruit
Length (mm)	14.53 + 4.341a	15.8 + 1.852a
Breadth (mm)	13.33 + 1.022a	14.76 + 1.766b
Height (mm)	11.14 + 0.759a	13.13 + 1.786a
Fruit Volume (mL)	7.25 + 3.18a	16.25 + 1.77a
Fruit Density (g/cm³)	1.52 + 0.212a	2.16 + 1.888a

The mean values in a row that do not share the same superscript are significantly different at $p < 0.05$

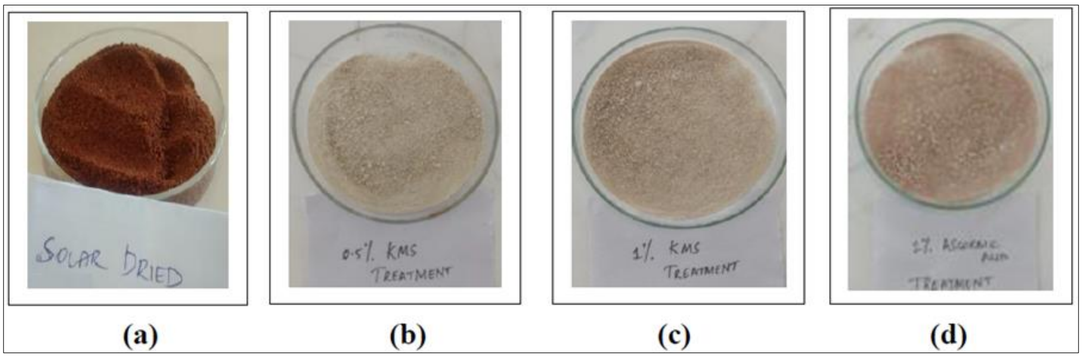
Fig 1: Aril from Raw Fruit

Fig 2: Aril from Ripe Fruit

Selection of the fruit powder for further studies

The obtained fruit powders with different pre-treatments is compared visually. Initially, a trial for 50 g of the arils is performed. The camachile powder that is obtained using solar drying produces a dark brown coloured fruit powder due the caramelisation of the sugars that are present in the fruit.

The colour change in the fruit is observed after the camachile arils are subjected to solar tunnel drying after 2 hours. Browning reaction is observed to have begun by the end of the third hour. After 6 hours of drying, the colour is retained with additional smell of burning. Nevertheless, the drying time is determined to be 18 hours after three consecutive constant readings is obtained. A caramelised aroma is being produced in the pulverise developed from these arils which will constrain the natural flavour of the manila tamarind. A similar kind of result is obtained by Swati Shukla, 2017 [19]. In addition to it, the longer drying times of the fruit in solar dryer enact as a hindrance to the process. Hence, an alternative method of tray drying is followed.



(a) Solar Dried Camachile Fruit Powder (b) Camachile Fruit Powder from 0.5% KMS Treatment (c) Camachile Fruit Powder from 1% KMS Treatment (d) Camachile Fruit Powder from 1% Ascorbic acid Treatment

Fig 3: Camachile Fruit Powders (CFP) obtained from different pre-treatments

The 0.5% KMS treatment gives a yield % of 13.6%, 1% KMS treatment gives a yield of 15.8% and treatment with ascorbic acid gives a yield of 12%. A very slight difference is observed in the yield %. However, the 0.5% KMS treatment gives a preferable colour visually (Fig 3.), thus is best acceptable powder and is subjected to sieve analysis which gives the size of fruit powder to be 300μ. This fruit powder is further studied for its functional and flow ability properties.

Table 2: Chemical Properties of the Raw and Ripe aril along with that of the seed and CFP

Chemical Properties	Raw Aril	Ripe Aril	Seed	CFP
Moisture (% w.b.)	77.92 + 4.32a	77.22 + 3.86a	10.71 + 1.457b	14.55 + 0.632b
Crude Protein (%)	3.51 + 0.001d	12.14 + 0.115a	10.51 + 0.002b	8.76 + 0.006c
Crude Fat (%)	1.77 + 0.28b	1.64 + 0.337b	4.13 + 0.153a	1.33 + 0.13b
Crude Fibre (%)	1.55 + 0.05c	2.05 + 0.051b	7.49 + 0.045a	2.02 + 0.021b
Ash (%)	0.42 + 0.015d	0.61 + 0.01c	3.42 + 0.015a	2.82 + 0.015b
Carbohydrates (By Diff)	14.92 + 3.43c	6.23 + 2.94c	63.69 + 1.207b	75.33 + 6.86a
Energy (kcal)	80.32	76.97	299.22	311.94
Ascorbic Acid (mg/100 g)	384.94 + 2.19a	136.66 + 2.19b	53.91 + 2.19c	ND
Titratable Acidity (%)	4.66 + 0.404a	4.2a	ND	ND
TSS (°B)	12.86 + 0.032b	15.33 + 0.032a	ND	ND
Sugar to Acid Ratio	2.77 + 0.15b	3.65 + 0.06a		
Total Phenols (mg phenols/100 g)	0.014 + 0.009a	0.016 + 0.001a	0.011 + 0.008b	ND
Reducing Sugars (%)	2.576 + 0.277b	4.222 + 0.192a	0.184 + 0.001c	ND
Anthocyanin Content (mg/L as CGE)	ND	0.525 + 0.006	ND	ND

ND = Not Determined; The mean values in a row that do not share the same superscript are significantly different at $p<0.05$

Moisture content: It is observed that the moisture content of ripe aril (77.22% + 3.86) is slightly lower than that of raw aril (77.92% + 4.32). However, both Pío-León *et al.*, 2013 and James. A. Duke, 1987 reported it to be 77.8 ± 2.0%. The later also reported the moisture content in the seed to be 13.5% and Galla Narsing Rao *et al.*, 2011 testified that white aril camachile powder had 14.7 ± 0.47% moisture. These are similar to the investigated value in the present study i.e. 10.71% + 1.457 for seed and 14.55% + 0.632 for camachile aril fruit powder.

Protein content: Ripen aril is found to have a higher protein content of 12.14% + 0.115 compared to the raw one's having just 3.51% + 0.001. The seed and the fruit powder has been reported to have 10.51% + 0.002 and 8.76% + 0.006 protein content respectively. Pío-León *et al.*, 2013 reported the protein content to be 2.59 ± 0.2 while James. A. Duke, 1987 reported it to be 3% in aril and 17.7% in seed. Galla Narsing Rao *et al.*, 2011 stated that white aril camachile powder had. 12.4% ± 0.34 protein.

Fat content: The values in the table 4.3 indicate that the fruit's seed has a high amount of oil content ie 4.13% + 0.153 when compared to the raw and ripe arils as well as fruit powder with 1.77% + 0.28, 1.64% + 0.337, 1.33% + 0.13 fat respectively. Longvah *et al.* (2017) [10] reported similar values of fat of 1.14 percent for the fruit aril.

Dietary fibre: Dietary fibre or total fibre content of Manila Tamarind is higher than in commonly consumed fruits e.g. apple 2.45%, mango 1.6% and orange 2.4% (Anon, 2009). But a contrasted pattern is observed here with it being higher in the seed (7.49% + 0.045) than in raw (1.55% + 0.05) and ripe fruit (2.05% + 0.051) and the fruit powder (2.02% + 0.021).

Ash content: Ash content was reported as 2.82 percent on fresh weight basis in Longvah *et al.* (2017) [10]. Seed is reported to have the highest among the ash content (3.42% + 0.015), followed by camachile fruit powder (2.82% + 0.015), ripe aril (0.61% + 0.01) and raw aril (0.42% + 0.015).

Carbohydrates and energy: *Pithecellobium dulce* arils can be considered as a low energy food, diet consumption of 100 g contributing less than 5% of the recommended caloric intake. The ripe fruits are found to have the least carbohydrate content as well as energy (6.23% + 2.94, 76.97 kcal). The raw fruit provides comparatively little higher amount of carbohydrates, thus providing more energy (14.92% + 3.43, 80.32kcal). Since the fruit powder contains a good amount of carbohydrate (75.33% + 6.86) as a consequence can be used as a good source of energy (311.94 kcal) by preparing some kind of energy-based drink using this. The high energy value of the seed (299.22 kcal) can be linked up with the fact that, the seed can be used for production of biofuel.

Ascorbic acid: Researchers assume that if a significant portion of vitamin C content is retained after processing, other nutrients are also likely to be preserved because the ascorbic acid is extremely unstable to heat, oxygen, light, pH, moisture content (Swathi Shukla, 2017) [19]. Accordingly, the raw fruit being rich in ascorbic acid as investigated (384.94 mg/100 g + 2.19) can be used in any kind of processing since, the ripen fruit has lesser quantity of the vitamin (136.66 mg/100 g + 2.19). The lower levels of ascorbic acid in the ripe fruit aril can be due to its high instability and that is why the ripe arils are sweeter than the raw ones. Even animals require small quantities of vitamin and mineral. The seeds having 53.91 mg/100 g + 2.19 vitamin C can be converted to fodder and used for animal feeding, helping in utilisation of all the vital parts of the fruit.

Titratable acidity, TSS and sugar to acid ratio: These are the internal maturity parameters that are usually measured to determine the best time to harvest the fruit. As the flesh of fruit forms it deposits nutrients as starch that transform to sugars as the fruit ripens. Hence, ripen fruits have higher TSS content than raw fruits 4.66% + 0.404 Titratable Acidity is determined in the present investigation for the raw arils which is slightly higher than that of ripe arils (4.2%) whereas Pío-León *et al.*, 2013 reported a much lower value of 0.89% ± 0.07. Though the sugar acid ratio is determined to be higher in ripen fruits (3.65°B + 0.06) than in raw one's (2.77°B + 0.15), the TSS of the fruit is found out to be slightly lower than the mentioned value of 16.7 ± 0.6. The higher acid content and lower sugar content in the raw fruit can thus be correlated to its sour and slight astringent aftertaste. The fruit acids are degraded, the sugar content increases and the sugar-acid ratio achieves a higher value during the ripening process.

Total phenols: Phenolic compounds are secondary metabolites widely found in fruits, mostly represented by flavonoids and phenolic acids. The phenol content is determined to be 0.014- 0.016 mg/100 g in the fruit aril and slightly lower in seeds (0.011 mg/100g). Significant difference is observed between the phenolic content of the fruit arils and the seed.

Reducing sugars and anthocyanin content: As the fruit reaches it maturity, the sugar levels increase. 4.222% + 0.192 of reducing sugars in the ripen fruit than 2.576% + 0.277 in raw fruit is enough to substantiate the statement. Moreover, anthocyanins hardly develop in the raw fruit and distinguished development of pink colour in the arils of white pods and complete transformation of arils in red colour in certain fruits from certain trees, is easily differed visually. Hence, 0.525 mg/L as CGE + 0.006 is the anthocyanin content estimated in the white arils. This is similar to the findings of Pío- León *et al.*, 2013 who stated that white arils have <1 mg Equivalent cyanidin-3-glucoside anthocyanin content.

Functional and flow ability properties of the samples: Food powders are widely used in manufacturing of the processed foods and hence various attempts are often made to correlate the flow properties of the powders to manufacturing properties. The powder behavior is multifaceted and thus obscures the endeavor to exemplify the powder flow.

For extruded, expanded and formed products, bulk density is an important parameter. The bulk density of the fruit powder is noted to have higher bulk density i.e. 0.504 g/cm³ + 0.002 while the true density is observed to be i.e. 0.516 g/cm³ + 0.002. Generally, higher bulk density is desirable for greater ease of dispersibility and reduction of paste thickness (Udensi and Eke, 2000) [21]. Low bulk densities of flour are good physical attributes when determining transportation and storability since the products could be easily transported and distributed to required locations (Agunbiade and Sanni, 2001). The result of this present research showed that the fruit powder has higher bulk density than composite flours at different levels of incorporation and should be used where such properties are required.

Compressibility index (2.451 + 0.218) and Hausner ratio (1.025 +0.002) are not intrinsic properties of the powder i.e., they depend on the methodology used. Based on the standard scale of flowability and taking into consideration the Compressibility Index and Hausner's Ratio, the camachile fruit powder has excellent flowability while it is poor in the case of formulated flours.

The fruit powder is found have 182.6% + 0.021 WAC. This could be due to molecular structure of the grains' starch which inhibited water absorption. OAC is an important characteristic that improves the mouth feel and retains the flavor with camachile fruit powder having the OAC of 110%. The fruit powder has 0.121 g/mL + 0.001 SC. 5.016 g/g dry weight WHC is recorded for the camachile fruit powder. This is obtained by dissolving hydrophilic components such as carbohydrates, lipids and proteins. The colloidal that is formed due to physical disturbance or mechanical stress of the fluid by trapping of air bubbles in folded in thin films is called foam. The battle between the gelatinisation of the starch and the gelation of the protein to interact with the available water determines the gelation capacity. Foaming Capacity is noted to be 2.127% and 8% least gelation capacity is experimentally determined. Suresh Chandra *et al.*, 2014 has reported the same LGC % of the composite flour developed with 5% blend of rice flour, green gram flour and potato flour and also for the pure wheat flour.

Conclusion

Ripe fruit arils are found to have better crude protein content *viz.* 12.14% + 0.115 than the raw aril and CFP. The ripe white aril has a very low anthocyanin content i.e. <1% which might be more in the pink arils. The yield of fruit powder from the camachile is considerably low i.e. 13% but it has very good flowability property based on Hausner's ratio and compressibility index. The particle size of the fruit powder is obtained as 300µ. Thus, it can be concluded that the neglected fruits in our nature can also be of great help. The manila tamarind is known to have high content of micronutrients and nutraceuticals and the fruit can be successfully exploited for the balanced diet of the individuals.

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