The Pharma Innovation Journal 2022; 11(9): 1283-1288

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(9): 1283-1288

www.thepharmajournal.com
Received: 13-06-2022
Accepted: 20-08-2022

Manoja V
Department of Food Process Engineering, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Sudha P
Department of Food Process Engineering, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Rajkumar P
Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Kumulur, Trichy, Tamil Nadu, India

Gurusamy K
Department of Food Process Engineering, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Jikky Jayakumar
Department of Food Process Engineering, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Corresponding Author:
Manoja V
Department of Food Process Engineering, Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Morphological characteristic analysis of dry fruits of annatto (*Bixa orellana* L.)

Manoja V, Sudha P, Rajkumar P, Gurusamy K and Jikky Jayakumar

DOI: https://doi.org/10.22271/tpi.2022.v11.i9o.15493

Abstract
The present research work was performed to explore the engineering properties of annatto (*Bixa orellana* L.) fruits and seeds in dried large and small variety. The geometric properties (length, breadth, thickness, arithmetic mean diameter, geometric mean diameter, sphericity, aspect ratio and surface area), gravimetric properties (bulk density, true density and porosity) and frictional properties (angle of repose and static coefficient of friction) were determined for small pods, large pods, small seeds and large seeds of annatto fruit by following standard methods. The moisture content of dried annatto fruits were ranged from 11.27 to 9.36% (w.b.) and for the seeds 6.67±1.5% (w.b.). The average arithmetic mean diameter of large pods was 30.33±3.19 mm and for small fruits was 23.49±2.29 mm. The true density, bulk density and angle of repose were also determined for small and large pods and seeds. The coefficient of friction was maximum (0.53±0.05) for small annatto pods in cardboard surface and minimum (0.14±0.057) for large dried pod in rubber surface. These properties finds application in developing a power operated decorticator to ease the separation of seeds from annatto pods without losing its valuable pigment present in its seed coat.

Keywords: Annatto pods, annatto seeds, physical properties, gravimetric properties, frictional properties, decorticator

1. Introduction
Annatto (*Bixa orellana* L.), is a historical multifunctional plant also known as Achiote or Lipstick Tree in Central and South America due to the reddish-orange pigment found on its seeds. Native to South and Central America, the *Bixa orellana* L. plant is also grown in Mexico, Peru, Ecuador, India, Indonesia, Kenya, and East Africa (Elias *et al*., 2002; Hirko & Getu, 2022) [8, 12]. An estimated 60% of the world's annatto is produced in Latin America, followed by Africa (27%) and Asia (12%) (Giuliano *et al*., 2003; Kang *et al*., 2010) [11, 13]. At present, the annual annatto production is nearly 30,000 tonnes which accounts for 11.8% in global market share for carotenoid (Kapoor & Ramamoorthy, 2021) [14].
The annatto pigment present in bright crimson pulp that covers the seeds (Giuliano *et al.,* 2003; Kang *et al.,* 2010) [11, 13]. The pigments in annatto comprise of major pigments namely bixin and norbixin along with minor compounds (Scotter, 2009) [24]. The FAO has suggested annatto extracts (Bixin and Norbixin) as a natural food additive (FAO, 2006) [9]. Being an apo carotenoid, annatto possesses various health advantages. It functions as an antioxidant and lowers the risk of eye-related issues as well as cancer, heart disease, and other degenerative diseases (Rivera-Madrid *et al.*, 2016; Balakrishnan *et al.*, 2021) [22, 6].
The commercial methods used for extracting the carotenoid pigment from dried annatto seeds are direct extraction using oil or aqueous alkali, or indirect extraction using solvents (Preston & Rickard, 1980; Kang *et al.,* 2010) [21, 13]. An oil or solvent based extraction produces a colorant that is mostly Bixin (Mortenson *et al.,* 2008; Kang *et al.*, 2010) [19, 13]. Norbixin is the aqueous alkali soluble pigment used as a colorant mainly in dairy industries (Giuliano *et al.,* 2003; Mortenson *et al.,* 2008; Kang *et al.*, 2010) [11, 19, 13].
According to MAFF (Ministry of Agriculture, Fisheries and Food, 1987 & 1993) [16,17], annatto was the most widely used natural colour additive in the UK, where per capita consumption was calculated to be 0.065 mg per kg of body weight per day based on pure colour component, or roughly 12.5% of the Acceptable Daily Intake (ADI). In terms of their modes of application to a variety of food products, the usage levels are necessary to get the desired colour shades (Collins, 1992; Levy & Rivadeneira, 2000; Scotter, 2009) [7, 15, 24].

The annatto tree can grow to a height of 3-5 m or even to 10m. The fruits are mostly heart shaped bi-valved (capsules), possesses seeds on each side of the capsules (Akshatha *et al.*, 2011) [2].
The capsules are covered with bristles which are soft when they are immature. At the time of maturation, the bristles around the pods turn into stiff and hard. An average of 30-60 numbers of seeds may found in each fruit (Alonso, 2004) [4]. The average length and breadth of the seeds are 0.3-0.5 cm and 0.2-0.3 cm. The shapes of the seeds differ from pyramidal to nearly conical (Vilar *et al.*, 2014) [26].
The dried annatto pods are traditionally beaten on the ground or in a bag with a stick to separate the annatto seeds. As a result, extraneous material is eliminated by screening and winnowing; nevertheless, caution must be exercised to prevent abrasion, which could lead to the loss of colour present in the seed coat (Math *et al.*, 2016) [18]. Mechanization is suggested to overcome the loss of valuable pigments during manual separation of annatto seeds. Hence, efforts had been taken in this study of determining the engineering properties of annatto to develop a decorticator for annatto.

2. Materials and Methods
2.1 Raw materials
Annatto fruits were procured from Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam, Tamil Nadu, India. The fruits were harvested manually as bunches, once the fruits were matured and dried. Based on the size of the fruits it is categorized as small and large fruits (varieties). The engineering properties of the pods and seeds were analysed to develop a decorticator to separate the seeds from the pods. For pods, pods along with seeds accounted for the analysis. In case of seeds, only seeds were considered for analysis.

2.2 Moisture content
According to Indian Standard methods for the analysis of oilseeds (IS:3579), using a hot air oven at a temperature of 105±1 °C for 24 hours, the moisture content of annatto seeds and pods was determined (Math *et al.*, 2016) [18]. The mean moisture content in wet basis was calculated using the equation suggested by Orhevba *et al.* (2016) [20]. To represent the moisture content in dry basis the relationship equation (2) was used as stated by Sahay and Singh (1996) [23].

$$\text{Moisture content (w.b.) \%} = \frac{\text{Wi}-\text{Wf}}{\text{Wi}} \times 100 \quad (1)$$

$$\text{Moisture content (d.b.) \%} = \frac{\text{M(wb)}}{100-\text{M(wb)}} \times 100 \quad (2)$$

Where,
Wi- Initial weight of the sample (g), WF- final weight of the sample (g), M (w.b.) - moisture content in wet basis (%), M (d.b.) - moisture content in dry basis (%).

2.3 Physical properties
To design and develop a decorticator, to DE shell the pods and to separate the seeds, the geometrical and gravimetric properties of pods and seeds were analysed.

2.3.1 Geometrical Properties
The average size of the pods and seeds was determined by measuring their length (l), breath (b) and thickness (t) using a digital vernier caliper having 0.01mm accuracy. The arithmetic mean diameter (D_a), sphericity (φ) and geometric mean diameter (D_g) were determined using the standard equations followed by Ahangarnezhad *et al.* (2019) [1]. This helps to design the hopper opening, and screen size and shape, and to determine the clearance between the roller and the concave netted unit

$$D_a = \frac{(l+b+t)}{3} \quad (3)$$

$$D_g = (lbt)^{\frac{1}{3}} \quad (4)$$

$$\varphi = \frac{D_g}{l} \times 100 \quad (5)$$

Where,
l- Length of the pods or seeds in mm, b- Breadth of the pods or seeds in mm¸ t - Thickness of the pods or seeds in mm.

The aspect ratio (R_o) was calculated with the values of length (*l*) and breadth (*b*) of the pods and seeds. The general equation to calculate the aspect ratio given by Unal *et al.* (2017) [25] and Ahangarnezhad *et al.* (2019) [1] was followed.

$$R_o = \frac{b}{l} \times 100 \quad (6)$$

The surface area (A_s) of the pods and the seeds was calculated using the formula (7).This helps to find the capacity of the developed machine.

$$A_s = \pi D_g^2 \quad (7)$$

2.4 Gravimetric properties
The properties like bulk density, true density and porosity of the dried annatto pods and seeds were analysed. The average bulk density of pods and seeds was determined using standard mass by volume ratio method. In a known volume of the container the samples are filled without any compaction until, it occupies the total volume of the container then the mass of the sample is measured. This gives the bulk density of the material.

$$\text{Bulk density } (\rho_b) = \frac{\text{Mass of the material,kg}}{\text{Volume of the container,m}^3} \quad (8)$$

The average true density was measured using water displacement method (Aviara *et al.*, 2007) [5]. The equation follows the volume of water displaced to the mass of the material added.

$$\text{True density } (\rho_t) = \frac{\text{Mass of the sample,kg}}{\text{Volume of water displaced, m}^3} \quad (9)$$

The porosity was determined using the bulk and true density relationship as mentioned in equation (10).

$$\varepsilon = 1 - \frac{\rho_b}{\rho_t} \times 100 \quad (10)$$

2.5 Frictional properties
Frictional properties like angle of repose and static coefficient of friction were studied for the annatto pods and seeds. These properties give a clear idea for the material selection while developing a machine.

2.5.1 Angle of repose
To determine the internal friction between the samples, and to understand flow of the material; the samples are discharged from a certain height to a known diameter of a circular base to form a heap. The angle of repose was measured as per the angle formed between the base and slope of heap formed on the base plate. The standard formula suggested by Alibas and Köksal (2014) [3] was used for this study.

$$\alpha = \tan^{-1}\frac{(2h)}{D} \quad (11)$$

Where,
A-angle of repose (°), h- height of the heap (mm) and D-diameter of the circular base plate (mm).

2.5.2. Static coefficient of friction
To choose a suitable material for fabrication of the decorticator, friction between the samples and different surface materials should be examined. The static friction was analysed with different base materials like rubber, cardboard, stainless steel, Aluminium and mild steel. It was calculated using the formula (12) given and followed by Sahay and Singh (1996) [23].

$$\mu = \frac{F}{N_f} \quad (12)$$

Where,
μ- coefficient of static friction, F- frictional force offered by the sample (N) and N_f - normal force (N).

2.6 Statistical analysis
The engineering properties of the samples were analysed at replicate; the mean and standard deviation of the observed data were analysed using SPSS version 16.0. An independent t- test was analysed for the different varieties of the fruits and seeds. The significant difference among the samples was tested at probability level of 5% (p<0.05).

3. Results and Discussion
The moisture content of dried pods of both the varieties (large and small) was in the range 11.27 to 9.36% (w.b.). The number of seeds in the large and small fruits was about 30-40 and 20-30 seeds, respectively. These observations are in accordance with the report made by Vilar *et al.* (2014) [26] and Math *et al.* (2016) [18]. Dried seeds of both the fruits variety had the moisture content around 6.67±1.5% (w.b.).

3.1 Physical properties of dried pods and seeds of large and small fruits
The mean length, breadth, thickness of dried large and small pods were 39.32±3.02 mm, 37.36±1.59 mm, 23.27±1.43 mm and 32.41±4.25 mm, 31.64±2.57 mm, 18.33±2.44 mm, respectively. In case of the dried seeds of the large and small fruits there is no significant difference in breath and thickness. The mean length, breadth and thickness of the dried seeds were 4.8±0.36 mm, 3.32±0.4 mm and 3.17±0.5 mm, respectively.
There is a significant difference at 5% (p<0.05) level in arithmetic mean diameter and geometric mean diameter of the dried pod and seeds. Since, it is based on the diameter of the sample. In terms of sphericity, surface area, volume and aspect ratio of dried seeds and pods, there is no significant difference between large and small fruits. The surface area of large and small pods were 3309.84 and 2224.24 mm^2; for large and small seeds the average values were 32.90 and 43.34 mm^2.
Figures 1-4 represent the arithmetic mean diameter, geometric mean diameter, sphericity and aspect ratio of dried pods and seeds.

3.2 Gravimetric properties of annatto fruits
The bulk densities of large and small pods were 25.766 kg/m^3 and 47.93 kg/m^3, respectively. The true density of both large and small pods was 1000 kg/m^3. The porosity of large and small pods dried were 95.21 and 97.4%, respectively.

3.3 Frictional properties of annatto fruits
The angle of repose for large and small pods were 41.669 and 44.425°, seeds of large and small annatto pods had 37.23 and 37.19°, respectively. The coefficient of friction was performed using different surfaces namely aluminum, stainless steel, rubber, cardboard and mild steel. Among that, dried small seeds had high coefficient of friction in all surfaces than small pods, large pods and large seeds. For aluminum surface, the small annatto seeds had the highest coefficient of friction (0.54±0.042) and the large pods had the minimum value of 0.26±0.010. For stainless steel, the small seeds had the maximum (0.42±0.01) and large pods had the minimum value of 0.26±0.095. The highest (0.47±0.001) and the lowest (0.14±0.057) value for coefficient of friction using rubber was obtained by small seeds and large annatto pods, respectively. Using cardboard material, the small pods obtained the highest value of 0.53±0.05 and the large pods had the lowest value of 0.48±0.03. For mild steel, small seeds obtained the maximum value of 0.41±0.018 and the large pods obtained the minimum value of 0.27±0.03. Averages of all observed values are given in Table 1.

Table 1: Coefficient of friction of large and small annatto pods and seeds

Materials	Large Annatto Fruits		Small Annatto Fruits	
	Pods	Seeds	Pods	Seeds
Aluminum	0.26±0.010	0.41±0.003	0.28±0.05	0.54±0.042
Stainless steel	0.26±0.095	0.40±0.076	0.28±0.02	0.42±0.01
Rubber	0.14±0.057	0.46±0.040	0.17±0.045	0.47±0.001
cardboard	0.48±0.05	0.50±0.01	0.53±0.05	0.50±0.01
Mild steel	0.27±0.03	0.39±0.01	0.29±0.05	0.41±0.018

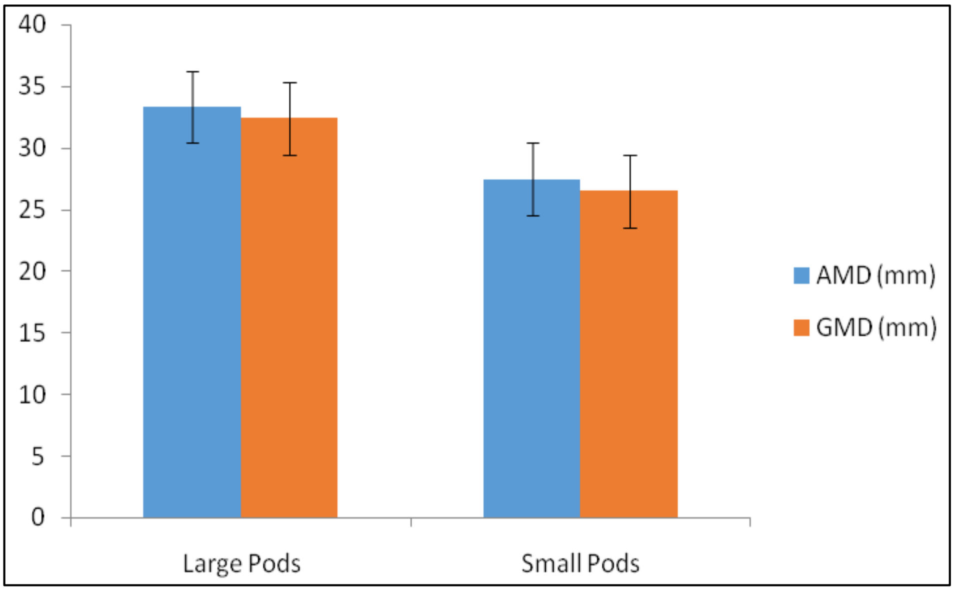

Fig 1: Arithmetic and geometric mean diameter of large and small annatto pods

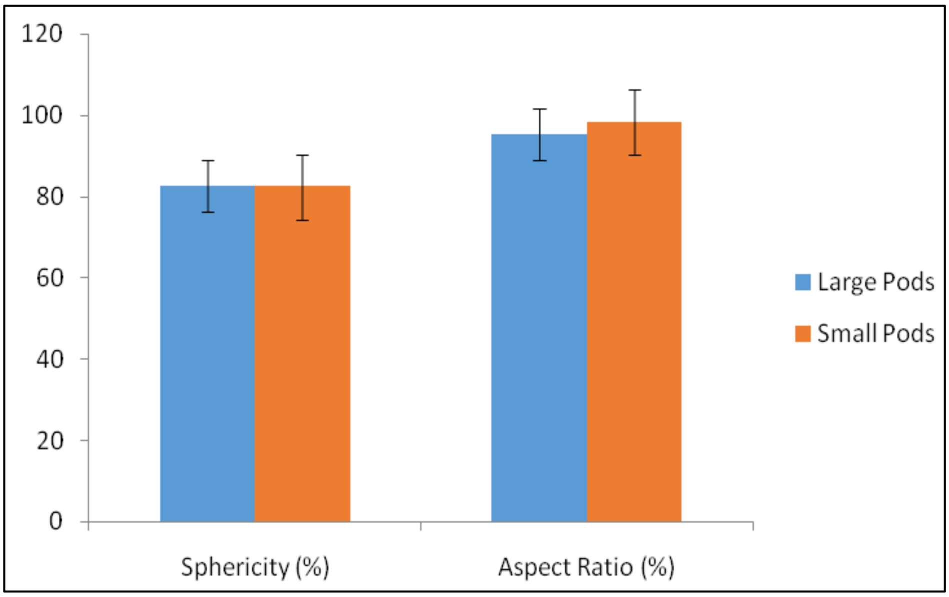

Fig 2: Sphericity and aspect ratio of large and small annatto pods

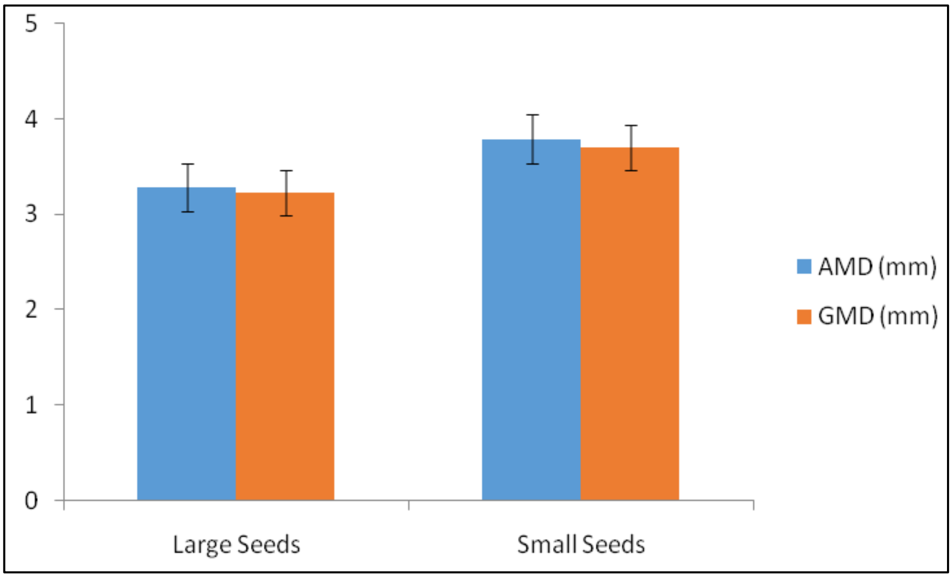

Fig 3: Arithmetic and geometric mean diameter of large and small annatto seeds

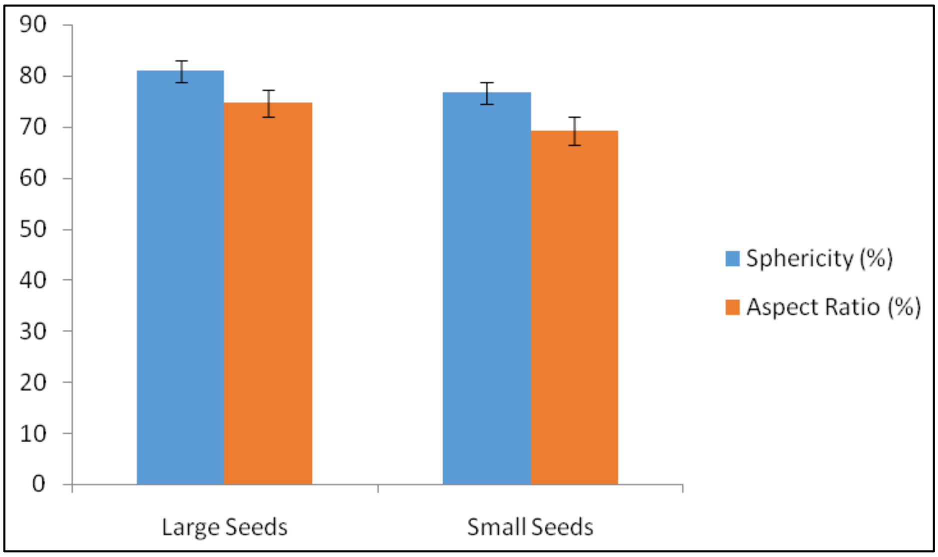

Fig 4: Sphericity and aspect ratio of large and small annatto seeds

4. Conclusion

The engineering properties of annatto pods and seeds were determined as a function of moisture content, with the range between 81.4-82.83% (w.b.) and 9.37-11.27% (w.b.), respectively. The major dimensions of seeds are the length, breadth, thickness, arithmetic mean diameter, geometric mean diameter, mean sphericity, aspect ratio, and surface area were found to higher for the large annatto pods than the small annatto pods. The aspect ratio of small seeds obtained from small annatto pods was higher than the seeds from large annatto pods. The findings of frictional and gravimetric properties will be useful for studying the complete engineering properties of annatto to design the processing machineries for annatto.

5. Future scope

The data obtained from this comparative study between the large and small annatto pods and seeds whose engineering properties will be useful to design and develop the processing and handling machineries for annatto especially decorticator to get an improved yield of pigments from seeds and to prevent its loss during the manual handling and separation of seeds from annatto pods.

6. Acknowledgement

The authors gratefully thank “Department of Science and Technology, Science and Engineering Research Board, Government of India” for funding this research work under Core Research Grant for the scheme entitled "Design and development of a decorticator for annatto (*Bixa orellana* L.) and development of prototype extraction unit with advanced techniques for bixin for sustainable use in food industry" .

7. References

1. Ahangarnezhad, Negar, Gholamhassan Najafi, and Ahmad Jahanbakhshi. Determination of the physical and mechanical properties of a potato (the Agria variety) in order to mechanize the harvesting and post-harvesting operations. Research in Agricultural Engineering. 2019 Jul 2;65(2):33-39.
2. Akshatha, Venugopalan, P Giridhar, GA Ravishankar. Morphological diversity in *Bixa orellana* L. and variations in annatto pigment yield. The Journal of Horticultural Science and Biotechnology. 2011 Jan 1;86(4):319-324.
3. Alibas, Ilknur, Nezihe Köksal. Convective, vacuum and microwave drying kinetics of mallow leaves and comparison of color and ascorbic acid values of three drying methods. Food Science and Technology. 2014;34:358-364.
4. Alonso, Jorge, Cristian Desmarchelier. Maytenus ilicifolia Martius (Congorosa). Bole tin Latin-American y del Caribe de Plantes Medicinals y Aromatics. 2007;6(1):11-22.
5. Aviara NA, SK Shittu, MA Haque. Physical properties of Guna fruits relevant in bulk handling and mechanical processing. International Agro physics. 2007;21:1.
6. Balakrishnan M, Gayathiri S, Preetha P, Pandiselvam R, Jeevarathinam G, Aniesrani Delfiya DS, *et al.* Microencapsulation of BIXIN pigment by spray drying: Evaluation of characteristics. LWT. 2021 Jan 1;145:111343.
7. Collins P. The role of annatto in food. Food Ingredients and Processing International; c1992 February. p. 23-27.
8. Elias MEA, Schroth G, Jeferson LV Macêdo, MSS Mota, Sammya Agra D'Angelo. Mineral nutrition, growth and yields of annatto trees (*Bixa orellana*) in agroforestry on an Amazonian ferralsol. Experimental Agriculture. 2002 Jul;38(3):277-289.
9. FAO-Food and Agriculture Organization of the United Nations. Annatto Extracts: Chemical and Technical Assessment; c2006. (Accessed on: May 24, 2007). ftp://ftp.fao.org/ag/agn/jecfa/cta_annatto.pdf
10. Giridhar P, Gondi Mahendranath, Akshatha Venugopalan, GA Ravishankar. Enhanced yield of food colorant annatto from seeds of *Bixa orellana* L. the efficacy of polyamines floral spray. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. 2012 Dec;82(4):553-556.
11. Giuliano, Giovanni, Carlo Rosati, Peter M Bramley. To dye or not to dye: biochemistry of annatto unveiled. Trends in Biotechnology. 2003 Dec 1;21(12):513-516.
12. Hirko, Biruk, Abukiya Getu. *Bixa orellana* (Annatto Bixa): A Review on Use, Structure, Extraction Methods and Analysis. Journal of Agronomy, Technology and Engineering Management; c2022.

13. Kang EJ, Campbell RE, Bastian E, Drake MA. Invited review: Annatto usage and bleaching in dairy foods. Journal of Dairy Science. 2010 Sep 1;93(9):3891-3901.
14. Kapoor, Leepica, Siva Ramamoorthy. Strategies to meet the global demand for natural food colorant BIXIN: A multidisciplinary approach. Journal of Biotechnology. 2021 Sep 10;338:40-51.
15. Lauro, Gabriel J, Jack Francis. Natural food colorants: science and technology. CRC press; c2000 Aug 24.
16. MAFF. Ministry of Agriculture, Fisheries and Food. Final Report on the Review of the Colouring Matter in Food Regulations 1973, Fd/FAC/6, Food Advisory Committee. London: HMSO; c1989.
17. MAFF. Ministry of Agriculture, Fisheries and Food, Food Surveillance. Dietary Intake of Food Additives in the UK: Initial Surveillance. London: HMSO, Paper No. 37; 1993.
18. Math RG, Ramesh G, Nagender A, Satyanarayana A. Design and development of annatto (*Bixa orellana* L.) Seed separator machine. Journal of Food Science and Technology. 2016 Jan;53(1):703-711.
19. Mortenson, Michael A, Zata M Vickers, Gary A. Reineccius. Flavor of whey protein concentrates and isolates. International Dairy Journal. 2008 Jan 1;18(6):649-657.
20. Orhevba, Bosede Adelola, Sunmonu MO, Ihiabe PA. Influence of Moisture Content on the Yield and Quality of Tropical Almond (Terminalia Catappa) Seed Oil; c2017.
21. Preston HD, Rickard MD. Extraction and chemistry of annatto. Food Chemistry. 1980 Jan 1;5(1):47-56.
22. Rivera-Madrid, Renata, Margarita Aguilar-Espinosa, Yair Cárdenas-Conejo, Luz E. Garza-Caligaris. Carotenoid derivates in achiote (*Bixa orellana*) seeds: synthesis and health promoting properties. Frontiers in Plant Science. 2016 Sep 21;7:1406.
23. Sahay KM, KK Singh. Unit operations of agricultural processing. Vikas Publishing House Pvt. Ltd; c1996.
24. Scotter, Michael. The chemistry and analysis of annatto food colouring: A review. Food Additives and Contaminants. 2009 Aug 1;26(8):1123-1145.
25. Unal Halil, Gokcen Izli, Nazmi Izli, Baris Bulent Asik. Comparison of some physical and chemical characteristics of buckwheat (Fagopyrum esculentum Moench) grains. CyTA-Journal of Food. 2017 Apr 3;15(2):257-265.
26. Vilar, Daniela de Araújo, Marina Suênia de Araujo Vilar, Fernanda Nervo Raffin, Márcia Rosa de Oliveira, Camilo Flamarion de Oliveira Franco, *et al*. Traditional uses, chemical constituents, and biological activities of *Bixa orellana* L: A Review. The Scientific World Journal. 2014 Jun 23;2014..