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EXTRACTION AND FUNCTIONAL PROPERTIES OF CELLULOSE FROM JACKFRUIT (*ARTOCARPUS INTEGER*) WASTE

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Keywords:

Cellulose, Functional properties, *Artocarpus integer*, Jackfruit, Applications

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ABSTRACT: Jackfruit peel is one among the under-utilized waste materials. In the present study, cellulose was extracted from de-pectinated peel. The peel was treated with alkali followed by a chemical process treatment. The yield of jackfruit cellulose was 27g / 100g of dry matter. Water and oil holding capability was a good retention value and higher hydration capacities of cellulose. The bulk, true densities and carr's index of cellulose were 0.17 ± 0.05 g/ml; 0.005 g/ml and 10.561%. Jackfruit cellulose foaming capacity was 2.99 % at pH 9 and foaming stability was maintained at pH 7, until the end of time (2h). Jackfruit peel as a potential source of natural cellulose has been comparing favourably with commercial grade cellulose used for food, pharmaceutical, and cosmetic applications.

INTRODUCTION: Artocarpus is a genus of roughly sixty trees and shrubs of Southeast Asian and Pacific origin, belonging to the mulberry family, Moraceae [1, 2]. Jackfruit was originally from India and spread out into tropic regions, including Indonesia [3, 4]. *A. integer* is locally known in Malaysia as 'Cempedak', is a close relative of jackfruit and wide jack trees. It has been widely planted in Thailand, Indonesia, *etc* [5]. *A. integer* plant has been used as traditional medicine to treat malaria [6, 7]. Jackfruit (*Artocarpus heterophyllus*) is one amongst the favoured fruits of India. A wide selection of applications, a big quantity of peel (which constitutes ∼ 59% of the ripe fruit) is discarded as waste [8]. Cellulose is the most compound with continuance units of D - glucose, a straight forward sugar.

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In the cellulose chain, the aldohexose units are in 6-8-membered rings known as pyranoses [9]. They're joined by single oxygen atoms (acetyl linkages) between the C-1 of 1 pyranose ring and therefore the C-4 of consecutive ring [10, 11]. Every β-1-4-glucopyranose bears 3 chemical groups teams and is ready to make intra and intermolecular H bonds that play a serious role in crucial the physical properties of cellulose [12, 13]. Cellulose, the most important constituent of all plant materials, forms into half to one-third of all plant tissues [14].

Cellulose is the most significant structural element that confers strength and stability to the plant cell walls [15] interrupted by hemicellulose and encircled by a polymer matrix. Cellulose can be isolated from various sources together with leaves, seeds, fruits, wood, cereal straws, different fibres [16], vegetable by-products like banana peel [17], cassava pulp [18], cassava peel and pulp[19] and cassava root and peel [20]. In recent years, the cellulose based materials has been increasing due to the demand for renewable resources and growing on region awareness [21].

The objective of this study was to extract cellulose from jackfruit peels and analysis of its functional properties.

MATERIALS AND METHODS:

Materials: Mature jackfruit peels were collected from the native market of Pudukkottai (district), Tamil Nadu, India. It had been known as *Artocarpus integer* ((Thumb.) Merr. - Moraceae). Plant species authentication was done at Botanical Survey of India (BSI), Coimbatore, South India (Ref no. BSI/SRC/5/23/2013-14/Tech/1714). For comparison study, commercial cellulose powder was purchased from M/s. Loba Chemie Pvt. Ltd., Mumbai, Maharashtra, India.

Methods:

Preparation of Jackfruit Peel Powder: Jackfruit was peeled manually to discard the edible part together with the seeds. The peels were cut into smaller pieces and treated according to the procedure [4, 22].

The treated jackfruit peels were then washed with boiling water and pressed to get rid of excess quantity of water. The peels were then dried in a cross flow drier at 65 ºC for eight h. The dried peels were grounded and packed in polyethene bags till further analysis.

Extraction of Cellulose from Jackfruit Peel: The extraction of cellulose procedure was supported methodology [10]. 25 g of the ground peel was taken for extraction of cellulose. The method followed is given in **Fig. 1**. The weight of cellulose obtained was recorded.

FIG. 1: EXTRACTION OF CELLULOSE FROM JACKFRUIT PEEL

Cellulose was kept in sealed container at temperature and prepared for analysis. The proportion of cellulose was calculated [23],

$$\text{Cellulose (\%)} = \frac{W_2}{W_1} \times 100$$

Where,

W_1 = weight of jackfruit peel powder (g) and

W_2 = weight of jackfruit cellulose (g)

Functional Properties: A food property characterizing the structure, quality, nutritional worth, and/or acceptableness of food products. A food functional property is decided by physical and chemical properties of a food. Examples of a functional property may hold bulk density, tapped density, true density, moisture sorption capacity *etc*.

Water and Oil absorption:

(a) Water Holding Capacity (WHC): According to Traynham [24] two grams of sample was weighed and dissolved in 38 ml of distilled H_2O in a centrifuge tube. The solution was then shakened for ten min. After ten min, the solution is placed in a centrifuge (3000 rpm, thirty min). Water in a centrifuge tube was weighed. Water holding capacity was calculated using the equation shown below;

$$\text{WHC} \ \frac{\text{g water}}{\text{g}} = \frac{\text{Weight of centrifuge + precipitate)} - \text{(Weight of centrifuge} - \text{sample weight)}}{\text{Weight of sample (g)}}$$

(b) Oil Holding Capacity (OHC): According to committee on codex specifications [25] two grams of sample were weighed and dissolved in 30 ml of palm oil in a centrifuge tube. The solution was then shakened for 10 min. After 10 min, the solution is placed in a centrifuge (2000 rpm, for 15 min). After centrifugation process, the supernatant was drained and wet sample precipitate was weighed. The result was expressed as a result of the gram of oil per gram of the sample. The oil retention capacity was calculated using the following equation,

$$\text{Oil Retention capacity (g)} = \frac{\text{(gram of oil)}}{\text{Weight of sample(g)}}$$

Swelling Capacity: According to the method described by [26, 27], 0.2 g was precisely weighed and transferred into a calibrated cylinder. Distilled water (10 ml) was then added to the cylinder. After mixing, the mixture was incubated for 18 h at room temperature. The packed volume was then recorded, and swelling was calculated as milliliters per gram of sample,

$$\text{Swelling capacity (ml/g)} = \frac{\text{ml of water displaced}}{\text{Weight of sample (g)}}$$

Emulsion properties:

(a) Emulsion Activity (EA): According to the method described by [28] with slight modifications. 3 grams of sample was weighed and transferred into a calibrated cylinder. Distilled water (50 ml) and 50 ml of soybean oil was then added to the cylinder. The emulsion mixture was equally divided into four 25 ml centrifuge tubes and centrifuged at 3000 rpm for 5 min. The Emulsion activity was calculated using the following equation is given below,

$$\text{Emulsion Activity (\%)} = 100 \times \frac{\text{Height of emulsified layer (cm)}}{\text{Height of total volume (cm)}}$$

(b) Emulsion Stability (ES): Emulsion stability is refers to the ability of an emulsion to resist amendment in its properties over time. Samples were able to review the emulsion stability (ES) once 1st day, 10th day, 20th day and thirty days of storage at 2 °C and 28 °C [29] with slight modification. Samples were centrifuged at 3000 rpm, for 10 min, at 2 °C and 28 °C. The initially emulsified layer volumes (V_{Ei}) was measured, once every storage period. Samples were centrifuged and the remaining emulsified layer volumes was measured (V_{Er}). Emulsion stability was calculated using the subsequent equation,

$$\text{Emulsion Stability (\%)} = 100 \times \frac{\text{VEr}}{\text{VEi}}$$

Bulk Density: A pre - weighed graduate cylinder was filled with 5 g of the sample and agitated slightly. The volume of the sample was recorded, the content of the cylinder was weighed, and the bulk density was expressed as weight per volume [30]. The bulk density was calculated using the subsequent equation,

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of the sample}}{\text{Volume of the sample}}$$

Tapped Density: A 5g of Powders (MCC) was gently poured into a 10 mL graduated the cylinder through a funnel. The tapped densities (TD) were obtained by manually tapping a graduate cylinder containing powder from a height of 25 mm [30]. The initial powder volume was evaluated and the cylinder was tapped fifty times until achieving constant volume and the subsequent reduction in volume was recorded. TD was calculated from the quantitative relation of mass of powder to perpetually tapped volume (g/ml),

$$\text{Tapped Density (g/ml)} = \frac{\text{Weight of the sample}}{\text{Tapped volume of the sample}}$$

Carr's index (%): Carr's index is an indication of the softness of a powder [30],

$$\text{Carr's index} = 100 \times \frac{\text{Tapped Density} - \text{Bulk Density}}{\text{Tapped Density}}$$

Hausner ratio: Hausner ratio may be a range that is correlated to the flowability of a powder [25],

$$\text{Hausner ratio} = \frac{\text{Tapped Density}}{\text{Bulk Density}}$$

True Density: The true densities (Dt), of cellulose were determined by the liquid displacement methodology [30] with slight modification. 0.5 g amount of cellulose was placed in a dry pre-weighed specific gravity bottle and also the rest filled with 50 ml xylene (SG - 0.86) immersion of fluid and the weight of the specific gravity bottle full of liquid has been evaluated. The density of the cellulose was calculated with the subsequent equation,

$$\text{True Density (Dt)} = w\,[(a+w) - b)] \times SG$$

Where, w is that the weight of powder, SG is specific gravity of solvent, a is weight of bottle + solvent and b is weight of bottle + solvent + powder

Angle of Repose: A funnel was clamped to its tip two cm above a graph paper placed on the flat surface. The powders were poured through the funnel until the apex of the cone thus formed merely reached the tip of the funnel [30]. The mean diameters of the bottom of the powder cones were determined and the tangent of the angle of repose was calculated using the equation,

$$\text{Angle of Repose} = \frac{h}{r}$$

Where, h is that the height of the heap of powder and r is that the radius of the bottom of the heap of powder

Foaming properties:

(a) Foaming Capacity (FC): Foaming capacity and foam stability were determined according to the method described by [31, 32] with slight modification.

Foam capacity (FC) was measured in terms of volume increase on whipping expressed as the percentage of original volume of the liquid. FC was calculated using the following equation is given below,

$$\text{Foaming Capacity (\%)} = 100 \times \frac{\text{Volume after homogenization} - \text{Volume before homogenization}}{\text{Volume before homogenization}}$$

(b) Foaming Stability (FS): Foam stability was expressed as percentage of froth volume remaining, in relation to initial foam volume at room temperature (25 ± 2 °C) after 5 min to 2 h,

$$\text{Forming Stability (\%)} = \frac{\text{Foam volume after time (t)}}{\text{Initial foam volume}}$$

RESULTS AND DISCUSSION:

Functional Properties of Cellulose:

Water and Oil absorption:

(a) Water Holding Capacity (WHC): The WHC of jackfruit cellulose was 2.18 g water/g obtained and its slightly higher than commercial cellulose 2 g water/g respectively. The WHC of jackfruit cellulose is found to be lesser than other peels including cellulose from banana peel (2.91 g water/g) [28] and pomelo albedo (8.9 g water/g) [33]. WHC is very important as it affects the texture, juiciness, and taste of food formulations and in particular the shelf life of bakery products (cakes, biscuits and cookies) [34]. Cellulose extracted from the natural source and chemically processed with acids or alkali can be added as a creaming agent or thickener to shredded cheese (parmesan), ice cream, fast food (burgers), powdered drink mixes and other commercial foods.

(b) Oil Holding Capacity (OHC): The OHC is a crucial factor in cellulose functionality. High OHC is indicative of possible of applications as emulsifiers for high fat food products like, mayonnaise, pound cake, ice-cream, whipped topping *etc*. [35]The OHC of jackfruit cellulose was (2.68 g oil/g) and it's higher than that for commercial cellulose (1.84 g oil/g). The OHC of jackfruit cellulose is found to be higher than other peel including cellulose from orange residue (2.01g oil/g) [36] and pineapple core (2.15 g oil/g) [37]. The OHC is of great importance of an industrial viewpoint, since it reflects the emulsifying capacity, this value a highly desirable characteristic in food products such as mayonnaise [38]. Both water holding capacity (WHC) and oil holding capacity (OHC) properties may be useful as thickening and emulsifying agents for food applications like, mayonnaise, ice-cream, cakes, cookies, *etc*. [27]

Swelling Capacity (SC): Swelling generally accepted as an indication of tablet disintegration ability [38] can be assessed by the determination of hydration capacity, swelling capacity and moisture sorption profile. The SC of jackfruit cellulose was 5 ml/g obtained and its higher than the commercial cellulose (4.15 ml/g). This is an indication that only a small portion of absorbed water actually penetrated the individual cellulose particles causing them to swell. The bulk of the absorbed water probably exists in a 'free' state between the particles [39].

Emulsion Properties: Cellulose samples were studied with emulsions prepared 0.5% (w/w).

(a) Emulsion Activity (EA): Jackfruit cellulose had the maximum emulsion activity at 28 °C (56.23%) and it was higher than commercial cellulose (47.36%). Jackfruit cellulose had a high emulsifying activity, because of its high oil holding capacity (2.68 g oil/g dried sample) than commercial cellulose (1.84 g oil/g dried sample). Jackfruit cellulose emulsion was found to be higher than the other cellulose emulsion properties to be reported from the pineapple peel (40.27%) [26] and banana peel (40.70%) [28]. Jackfruit cellulose with a high oil holding capacity is also suitable for products that need to improve in texture, as a creaming agent or thickener to shredded cheese (parmesan), ice cream, fast food (burgers), powdered drink mixes and other commercial foods.

(b) Emulsion Stability (ES): Additionally the overall stability of an emulsion cellulose samples is shown in **Fig. 2**. It was observed that after thirty days of storage, the jackfruit cellulose emulsion (oil-water) stored at 28 °C reported a stability of 88.89 to 85.4% indicating the higher stability levels of these emulsions.

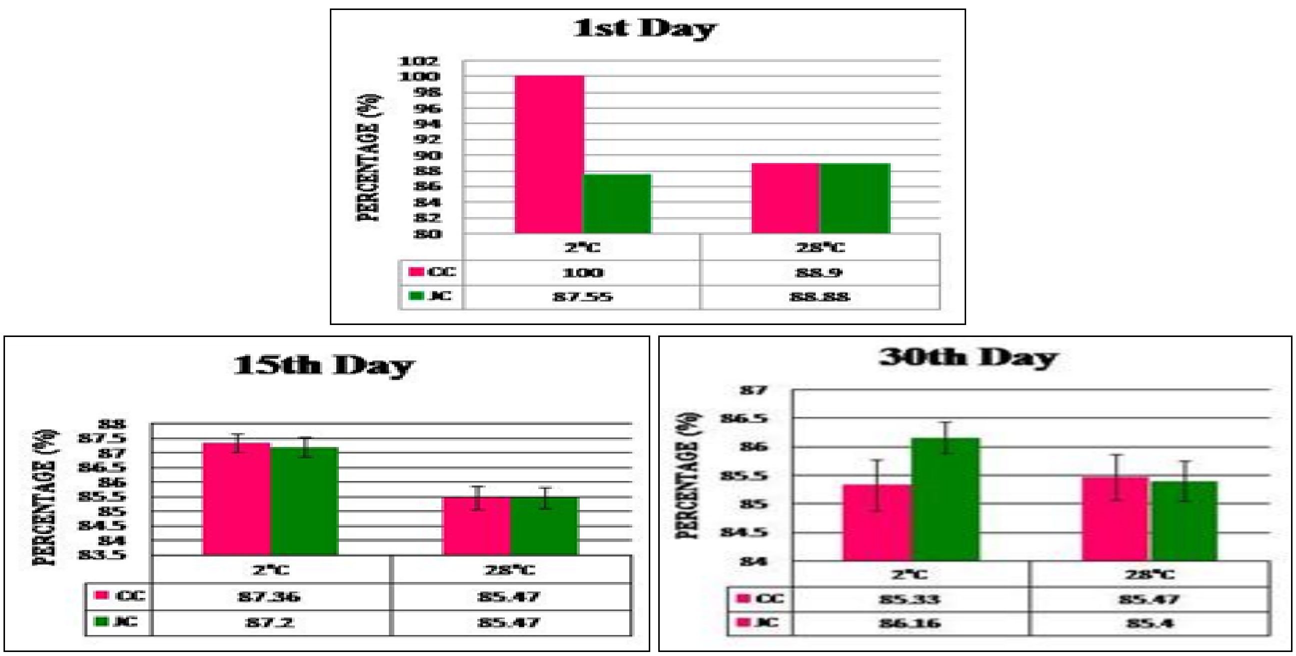

FIG. 2: EMULSION STABILITY FOR 30 DAYS AT 2 °C AND 28 °C
(*CC - Commercial Cellulose, JC - Jackfruit Cellulose)

Bulk Density (BD): The bulk density of jackfruit cellulose was (0.17 ± 0.05g/ml) obtained and its lesser than commercial cellulose (0.30 ± 0.005 g/ml). The BD of jackfruit cellulose is found to be lesser than other peels including cellulose from banana peel (0.646 ± 0.27g/ml) [23] and orange peel (0.305 g/ml) [40]. This increased porosity (lower density) facilitates compressibility, *i.e.*, the densification of a powder bed due to the application of stress [41].

Since BD of powders depends on the combined effect of interrelated factors, such as the intensity of attractive inter-particle forces, particle size and number of contact points [42], it is clear that a change in any of the powder characteristics may result in a significance change in the powder bulk density. There is an intricate relationship between the factors affecting powder bulk density, as well as surface activity and cohesion.

Tapped Density (TD): The tapped density of jackfruit cellulose was found to be (0.19 ± 0.05 g/ml) lesser than commercial cellulose (0.38 ± 0.05 g/ml). The TD of jackfruit cellulose is lesser than other cellulose from *Lageriana siceraria* (0.39 g/ml) [30]. The TD of a material can be used to predict both its flow properties and its compressibility.

Carr's Index: The Carr's compressibility index below 16% indicated smart flowabilities, whereas values are 35% higher indicate cohesiveness [43]. Carr's index of jackfruit cellulose was found to be (10.561%) lesser than the commercial cellulose (21.05%). The Carr's index of jackfruit cellulose is lesser than the other cellulose from *Lageriana siceraria* (23.5 %) [30]. The *Carr index* is frequently used in pharmaceutics as an indication of the flowability of a powder.

Hausner Ratio: In general, the Hausner ratio larger than 1.25 indicates poor flowability [44]. The Hausner ratio of jackfruit cellulose was found to be (1.10 ± 0.01) flowability is good, compare to commercial cellulose (1.25 ± 0.04). The flow properties of a powder are essential in determining the suitability of a material as a direct compression excipient [39]. MCC is reported as an excipient (diluent) in oral powder and capsules extemporaneously compounded for paediatric use. Capsules and powders are prepared from commercial tablets containing 10 mg of nifedipine, which was mixed with different amounts of MCC in a mortar with pestle using standard geometric dilution.

True Density: True density is the density of the solid material excluding the volume of any open and closed pores. In general, the "higher the true density of a powder, the better the compressibility" [45] (Azubuike and Okhamafe 2012). The true density of jackfruit cellulose was (0.005 g/ml) obtained and its higher than commercial cellulose (0.004 g/ml). The true density of jackfruit cellulose is found to be lesser than other cellulose from *Lageriana siceraria* (0.23 g/ml) [30]. The density of particles, powders, and compacts is an important property affecting the performance and function of many pharmaceutical materials.

Angle of Repose: Angle of repose of powder is an important in determining good powder flow property. There are many factors affecting the angle of repose of a material which include particle size, individual material, and moisture and measurement method of angle of repose. The angle of repose of commercial cellulose was found to be (44°) higher than jackfruit cellulose (27°). Angles of up to 40° indicated reasonable flow potential of the solid powders, whereas those samples with angles greater than 50° exhibit poor or absent flow. The angle of repose of jackfruit cellulose was found to be lesser than other cellulose from *Lageriana siceraria* (32.9°) [30] and groundnut husk (44.23°) [43]. The angle of repose, a traditional characterization method for pharmaceutical powder flow, also used in other branches of science (*i.e.* geology) to characterize solids.

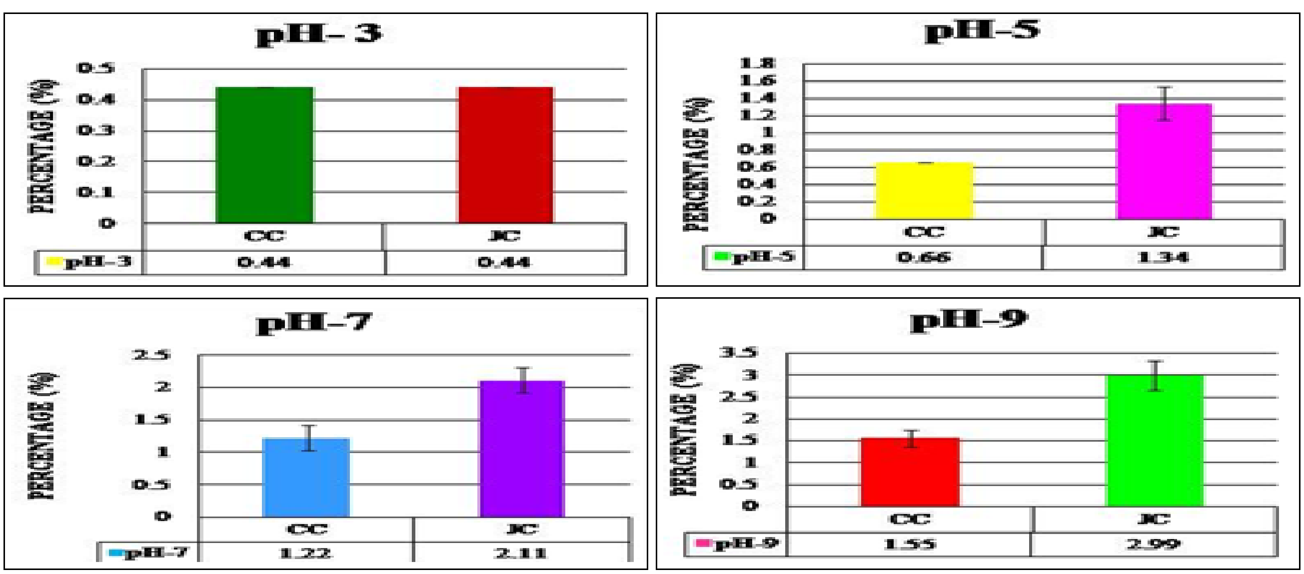

FIG. 3: FOAMING CAPACITY OF CELLULOSES
(*CC - Commercial Cellulose; JC - Jackfruit Cellulose) as affected by pH values

Foaming Properties:

(a) Foaming Capacity (FC): Foaming capacity (FC) is used to determine the ability of foam mixture is a colloid of many gas bubbles trapped in a liquid or solid [31]. The FC of both celluloses (commercial jackfruit) as affected by pH values 3, 5, 7 and 9 are shown in **Fig. 3**. FC of cellulose data showed that the maximum increase in foam volume of jackfruit cellulose was 2.99% at pH 9.0 followed by 2.11% at pH 7.0. However, the lowest volume of the foam 0.44% of both celluloses (commercial and jackfruit) was determined at pH 3.0. The results showed that the foaming capacity of jackfruit cellulose is increased by increasing the pH values.

(b) Foaming Stability (FS): The FS of commercial cellulose data should be stable from 1 min to 2 h of all the pH variation compared to jackfruit cellulose is shown in **Fig. 4**. The highest foam stability of both celluloses (commercial and jackfruit) was recorded at pH 3 for 2 h. At pH 5 and 9, the foaming stability of jackfruit cellulose decreased gradually until 60 min. At pH 7, the jackfruit cellulose foaming stability was maintained, until the end of time (2h).

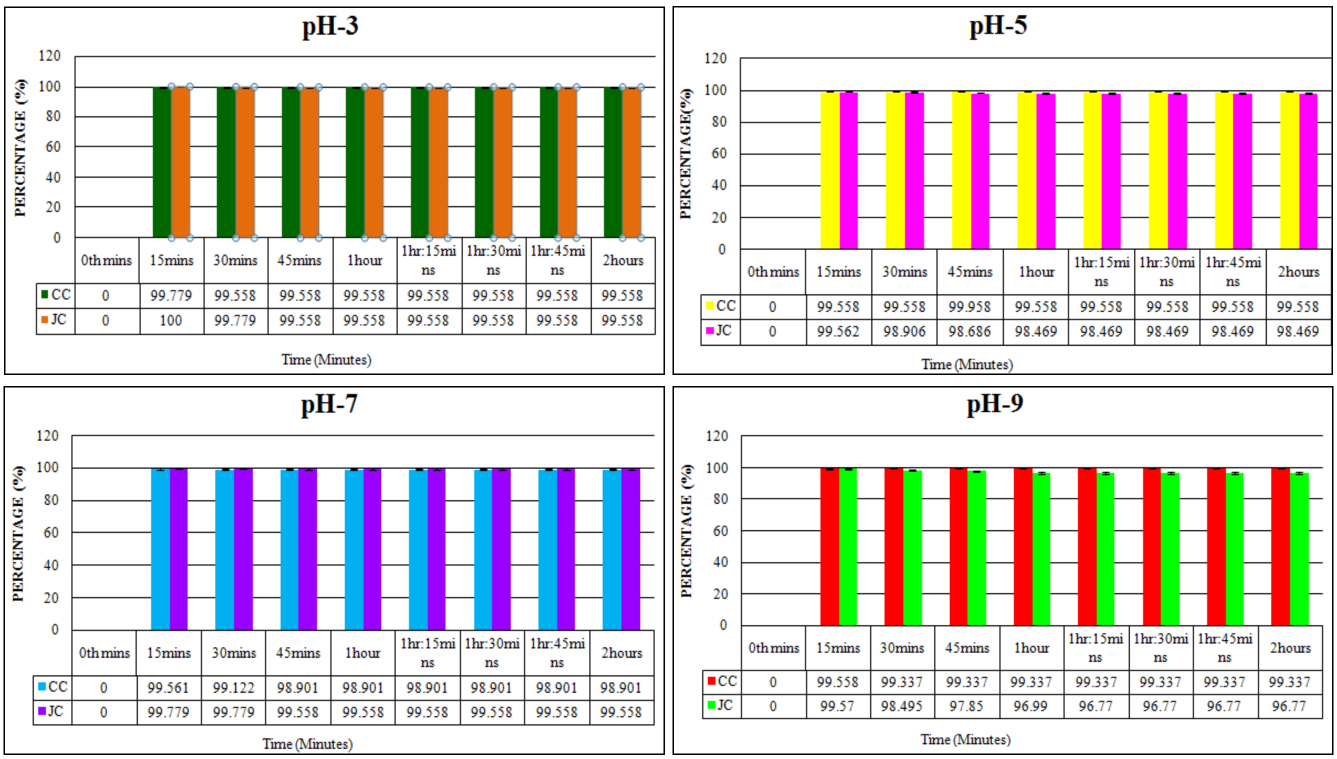

FIG. 4: FOAMING STABILITY OF CELLULOSES

(*CC - Commercial Cellulose; JC - Jackfruit Cellulose) as affected by pH values

CONCLUSION: Cellulose was extracted from the de-pectinated peel. The peel was treated with alkali followed by a chemical process treatment [46]. The flow properties of the jackfruit cellulose like bulk, true densities 0.17 ± 0.05 g/ml; 0.005 g/ml, Carr's index is 10.561% and Hausner ratio is 1.10 ± 0.01, indicates good flowability. It was observed that after thirty days of storage, the jackfruit cellulose emulsion stored at 28 °C reported a stability of 88.89 to 85.4%. Indicating the higher stability levels of the emulsions. Finally, the high emulsion activity and stability of the jackfruit cellulose indicates that, they might be used as ingredients in several formulations like salad dressing, ice creams, and cake batters. Results show that jackfruit peel could be utilized for manufacturing the byproducts like alpha cellulose, micro-crystalline cellulose and carboxymethyl cellulose. Cellulose derivatives are often used to modify the release of drugs in tablet and capsule formulations and also a tablet binding, thickening agent, rheology control agent and water retention.

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