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Engineering Properties of Different Commercial Grades of Sago (Sabudana)

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Authors' contributions

This work was carried out in collaboration among all authors. Author TK designed the study, wrote the protocol and wrote the first draft of the manuscript. Author MSS help in conducting the experiment and managed the analyses of the study. Authors SR, NAG, CP, VSK and VB managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Sago is a traditional food product of India made exclusively from fresh wet cassava starch. The engineering properties of different commercial grades of sago, developed by roasting and steaming process were investigated. The physical properties (moisture content, size, shape (sphericity), bulk density, particle density, porosity), functional properties (solubility index, swelling power, cooking time, cooking loss, oil absorption index), pasting and dynamic rheological properties were studied. The size of the roasted commercial and steamed nylon sago varied from 3.57 to 4.11 mm and from 2.50 to 5.88 mm, respectively. The shape (sphericity) of different grades of sago ranged from 0.63 to 0.86. The bulk density and particle density of the different commercial and nylon sago varied from 420 kg m^{-3} to 800 kg m^{-3}. The swelling power (39.59 g/g) of the steamed nylon sago was high as

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compared to that of roasted sago. The steamed nylon sago showed a reduction in peak viscosity, breakdown and final viscosity as compared with the roasted commercial sago. A decrease in cooking loss with an increase in cooking time was noticed in the roasted commercial sago, whereas increase in cooking loss with increase in cooking time was noticed in the steamed nylon sago. The elevated peak viscosity value showed reduction in pasting temperature for both steamed and roasted sago. The different grades of sago gel behaved like a dilute solution due to increase in loss modulus over storage modulus.

Keywords: Commercial grade; engineering properties; roasting; sago; steaming.

1. INTRODUCTION

The production and consumption of roots and tuber crops like cassava attaches a significant importance in support of the rural food security. Compared with other cereals and tuber crops, cassava has the potential to produce the highest yield in terms of carbohydrates or calories [1]. Tamil Nadu stands first in production and processing of cassava into starch and sago meeting 80% demand at national level in food and non-food areas. In Kerala and North-Eastern States, cassava is consumed directly by the people whereas in Tamil Nadu more than 80% production of cassava tubers is being processed into sago and starch [2]. In India, Cassava is grown over an area of about 0.20 Million hectares mostly from Tamil Nadu, Kerala, Andhra Pradesh, Karnataka and a few North-Eastern states with a production of 4.34 Million Tonnes [3]. Sago is the only major product obtained from fresh cassava tubers [4,5,6]. There are over 400 factories in Salem, Namakkal and Dharmapuri districts of Tamil Nadu extracting starch and manufacturing sago from the cassava tubers. Sago industry is an agro based seasonal industry and it has huge employment potential [7,8]. The flowchart of the processing operations generally adopted in India to extract starch from cassava roots is shown in Fig. 1.

Sago (sabudana) is a processed edible starch marketed in the form of small globules or pearls [9]. It is easily digestible, rich in carbohydrate and its size generally ranges from 2 to 4.5 mm, produces a sudden boost of energy when it is consumed [10]. Since sago is rich in carbohydrate it is highly recommended for quick recovery of patients. When cooked, sago turns from opaque white colour to translucent and becomes soft and spongy. Sago is very heat sensitive, if it is subjected to fry, it will turn into a sticky, gluey mass, which is nearly impossible to separate. It is a traditional processed food product of India and commonly used as a food (known as khichadi) during festive season and fasting in western and central part of India (Maharashtra and Madhya Pradesh) and used as baby food (West Bengal). It is also used as a food thickener in several food preparations and in South India, it is used to make Kheer by adding milk [10]. The flowchart of the unit operations followed for sago production is shown in Fig. 2.

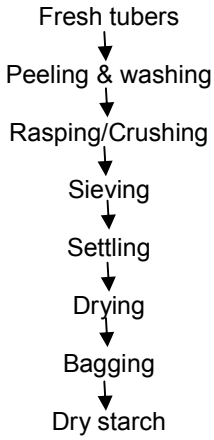

Fig. 1. Schematic diagram of native cassava starch production

The subsequent washed, settled and compacted starch is milled, then agglomerated into globules on power driven globulator and sieved to remove the oversized and undersized globules which are reprocessed [11].

The globules are partially gelatinized by roasting on shallow iron pans heated by wood fires, then stored overnight before being sun dried [12,13]. After sun drying, the globules are fed into a rotary polisher and then graded over a reciprocating sifter before being bagged for sale. Sago is generally classified into two types viz. Roasted sago (commercial sago) and Steamed sago (Nylon sago) based on the type of heat treatment after globulation. They are further divided into different grades viz., Commercial (special, best, milky white) and Nylon (ceylon, pearl).

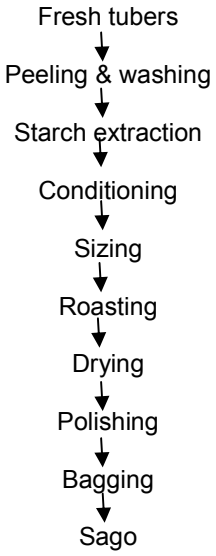

Fig. 2. Schematic diagram of sago (Sabudana) production

Nylon Sago is glassy and has more transparency in its raw appearance, whereas roasted sago has no transparency. The colour of the two grades are also different as nylon sago becomes a glowing transparent cream-yellow colour when cooked, whereas roasted sago retains the original natural white colour like a milk. Basic information on the engineering properties is of great importance and help to the scientists, engineers and processors towards efficient design of processes and equipments development [14]. The knowledge of engineering properties helps to analyze the behavior of sago during processing especially before and after roasting and also in the design of process equipments. Therefore this study was focused to determine the important engineering properties of the different commercial grades of sago.

2. MATERIALS AND METHODS

2.1 Raw Materials

Three different commercial grades of roasted sago (special (CS), best (CB) and milky white (CM)) and two types of steamed nylon sago (Ceylon (NC) and Pearl (NP)) are shown in Fig. 3 were obtained from the SAGOSERVE, Salem, Tamil Nadu.

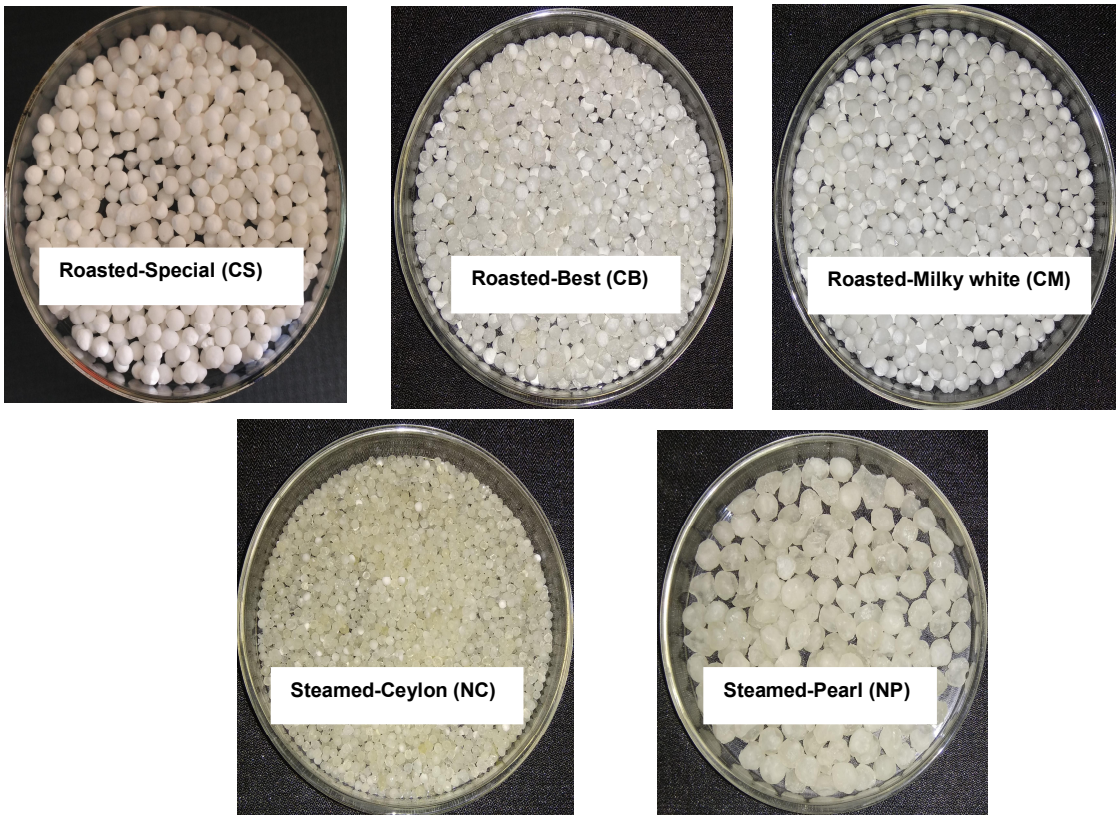

Fig. 3. Different commercial roasted and steamed grades of sago

2.2 Physical Characteristics

Physical characteristics such as moisture content, size, shape, bulk density, particle density and porosity were measured for different types of sago. The data obtained from these parameters will be useful in the design and development of sago handling machines and equipment.

2.2.1 Moisture content

The moisture content of sago was determined by using a hot air oven as per the procedures outlined by Association of Official Analytical Chemists [15]. The temperature was maintained at 50ºC. The sago was dried for 7 h till it reach bone dry condition.

The moisture content was calculated using the formula in equation 1.

$$MC, \%\,(d.b) = \frac{W_w}{W_d} \times 100 \quad (1)$$

where,

MC, % (d.b)- moisture content, per cent (dry basis).
W_w - weight of water evaporated to reach bone-dry condition, g.
W_d - weight of dry matter content present, g.

2.2.2 Size

The size of a physical object is generally necessary if the object has to be satisfactorily described. Three samples, each weighing 500 g were randomly used to determine the size of the different commercial sago. Hundred sago samples were picked out randomly from each of three samples and a total of 300 sago sample were mixed thoroughly. Finally, hundred sago were randomly selected and labelled for easy identification. This method of random sampling was similar to the one followed by [16,17]. Three principal dimensions namely length, width and thickness were measured for each sago using a vernier caliper having a least count of 0.01 mm as reported by [18,19,20]. The mean diameter of the sago was calculated in terms of arithmetic mean (d_m) and geometric mean (d_g) from the dimensions recorded using the equation 2 and 3.3

$$d_m = \frac{(a+b+c)}{3} \quad (2)$$

$$d_g = (abc)^{\frac{1}{3}} \quad (3)$$

Where,

d_m - arithmetic mean diameter, mm.
d_g - geometric mean diameter, mm.
a - longest intercept, mm.
b - longest intercept normal to *a*, mm.
c - longest intercept normal to both *a* and *b*, mm.

2.2.3 Shape

The shape of sago was expressed in the terms of sphericity. Sphericity measures the spherical nature of a given solid. The sphericity was calculated by tracing the magnified shadow of a sago fruit in its three mutually perpendicular positions on a graph sheet, with the help of an overhead projector [16,21]. The projected area, diameters of the largest inscribing and the smallest circumscribing circles (for sphere like materials) and length and diameter of the largest inscribing and the smallest circumscribing cylinders of the projected view for cylinder like materials were measured in the shadow graphs. The sphericity was calculated by using the formula in equation 4.

$$S = \frac{d_i}{d_C} \quad (4)$$

Where,

S - sphericity, decimal.
d_i - diameter of the largest inscribing circle, mm.
d_c - diameter of the smallest circumscribing circle, mm.

The shape of the sago product was adequately defined by using the descriptive terms mentioned for fruits and vegetables [18].

2.2.4 Bulk density

Bulk density was calculated as the ratio between mass and total volume (including pore space) of the sago. The bulk density of sago was determined by pouring it from a height of 20 cm into a container of known volume and striking off the top level. Then the contents were weighed [16]. The bulk density was calculated using the equation 5.

$$Bulk\ density\ of\ the\ sago\ (\rho_b) = \frac{\text{Mass of sago (kg)}}{\text{Total volume of sago (m}^3\text{)}} \quad (5)$$

The experiment was conducted at the moisture content range between 66.66 and 13.63 per cent (d.b). Each test was replicated thrice and the average value was recorded.

2.2.5 Particle or true density

Particle density is generally recommended to determine storage capacity and silos fabrication or space requirement for particular mass of commodity. The Particle density is defined as the ratio of the mass of the particles to the true volume of the particles. Particle density ρ_p ($kg.m^{-3}$) was measured using a pycnometer method (BLAUBRAND, Wertheim, Germany) with an inside volume of 0.516 m^3 [18]. In this experiment, toluene was used as non water-soluble liquid. At 28°C ambient temperature, the density of toluene was noted as 867 $kg.m^{-3}$. The particle density of sago was calculated using the following equation 6.

$$Particle\ density\ of\ the\ sago\ (\rho_p) = \frac{\text{Mass of sago (kg)}}{\text{True volume of sago (m}^3\text{)}} \quad (6)$$

2.2.6 Porosity

Porosity is the percentage of air between the particles compared to a unit volume of particles. The porosity of the roasted sago was computed using the equation 7 [22]

$$Porosity\ (\boldsymbol{\varepsilon}) = 1 - \frac{\rho_b}{\rho_p} \text{x} 100 \quad (7)$$

Where,

ε is the porosity, %
ρ_b is the bulk density, kg m^{-3}
ρ_p is the particle density, kg m^{-3}

2.3 Functional Properties

2.3.1 Solubility index

Solubility index (%) of the cassava starch was determined using [23]. The 2.5 g of sago sample was weighed into 50 ml centrifuge tube and heated in 30 ml distilled water in a water bath at 60°C for 30 min without mixing and then centrifuged at 3000 rpm for 10 min. The supernatant was dried at 105°C to constant weight and the weight of the dry solids was measured. All the experiments were made in triplicate. The following equation (8) was used to calculate the solubility index.

$$\text{Solubility index (\%)} = \frac{m_s}{m_d} \times 100 \quad (8)$$

Where,

m_s - Weight of soluble starch (g)
m_d –Weight of starch sample on dry basis (g)

2.3.2 Swelling power

Swelling power (g/g) was determined by modified method of Betancur, et al. [24]. 2.5 g of the sago sample was weighed into 50 ml centrifuge tube. Then 30 ml of distilled water was added and mixed gently. The sample was heated in a water bath at 60°C for 30 min and centrifuged at 3000 RPM for 10 min. The supernatant was decanted immediately after centrifuging. The weight of the sediment was taken and recorded. The swelling power of sago was calculated using the equation 9.

$$\text{Swelling power } (^{g}/_{g}) = \frac{\text{Weight of sedimented starch paste (g)}}{\text{Weight of starch sample on dry basis x (100} - \text{\% solubility)}} \text{x} 100 \quad (9)$$

2.3.3 Cooking time and cooking loss

Cooking properties of the sago were evaluated for optimal cooking time (OCT) in triplicate. Optimum cooking time (OCT) of sago sample was determined as per the approved method (66-50, AACC, 2000) corresponds to the disappearance of the white core of the sago with softness. To evaluate optimum cooking time (OCT), 10 g of sago were cooked in 300 ml of distilled water. Cooking loss (%), is the amount of solid residue in cooking water was determined by evaporating the cooking water in a convective hot air oven at 105ºC for 16 h [25]. The weight of residue was expressed as percentage of original sago sample.

2.3.4 Oil absorption index

Oil absorption index (OAI) of the sago samples was determined using the method of Liadakis, et al. [26]. Sunflower oil (5 ml) was added to 0.5 g of ground sample in a 15 ml graduated glass centrifuge tube. The sample was agitated on a vortex mixer for 1 min and allowed to stand at room temperature for 30 min. The contents were centrifuged at 3000 x g for 20 min and the volume of free oil was noted.

OAI (g/g) = weight of the oil absorbed sago sample (g) / weight of the sago sample (g) (3.10)

2.4 Pasting Properties of Sago

The viscosity of control and ultrasound treated samples were determined using a rapid visco analyzer (RVA-4, Newport Scientific and Warriewood, Australia). The powdered sago sample (2.5 g dry weight) was accurately weighed out into the aluminum canister and distilled water (25 g) was added and mixed well. The canister was placed in the RVA unit and the heating/cooling cycle was performed according to Standard I profile. The slurry was heated from 50 to 95ºC at 12ºC/min and held at 95ºC for 2 min. The paste was cooled to 50ºC at 12ºC/min and finally maintained at 50ºC for 2 min. The parameters such as peak viscosity (PV), breakdown viscosity (BV), setback viscosity (SV) in terms of centipoises (cP) and pasting temperature (PT) were measured. In addition, setback viscosity, SV(final - trough viscosity), disintegration rate, DR % (ratio of breakdown to peak viscosity) and retrogradation rate, RR % (ratio of setback to peak viscosity) were also calculated.

2.5 Dynamic Rheological Properties of Sago

In dynamic oscillation measurements, the potential energy and the energy that is dissipated as heat may be separated into storage modulus and loss modulus, respectively. Storage dynamic modulus (G') is a measure of the energy stored in the material and recovered from it per cycle while the loss modulus (G") is a measure of the energy dissipated or lost per cycle of sinusoidal deformation [27]. The ratio of the energy lost to the energy stored for each cycle may be defined by tan δ, which is another parameter indicating the physical behaviour of a system. In dynamic oscillation measurements, the frequency sweep of the two moduli (G' and G"), may be used to distinguish between the elastic and viscous properties of a material over a spectrum of times. When the viscous properties dominate, G" exceeds G', and *vice versa* (G' > G") when the elastic properties prevail. The dynamic rheological properties (storage modulus, loss modulus and phase angle) for the 10% (w/v) gel suspension of the sago samples obtained from RVA studies were determined using Rheoplus MCR 51 Rheometer (M/s Anton Paar GmbH. Germany) at 30ºC, using a parallel plate geometry system (PP20-SN5912, 1 mm diameter) at 1 mm gap. The following experimental conditions were selected: frequency 1 to 10 Hz; strain of 1 per cent (%). For each treatment, storage modulus (G'), loss modulus (G'') and phase angle (δ) were recorded and the measurements were conducted in duplicates.

2.6 Statistical Analysis

Data analysis was performed using R software. One way Analysis of variance (ANOVA) and pairwise mean comparison were performed using Tukey's test to determine the significant effect of the independent variables on the response variables. The treatments and their interactions were compared at $P<0.05$ level.

3. RESULTS AND DISCUSSION

3.1 Physical Properties

The moisture content, size, sphericity, bulk density, particle density and porosity of different commercial grades of sago are shown in Table 1.

Analysis of data showed that there was a significant difference between moisture content in all the different grades of sago. The lowest moisture content (8.65%) was noticed for Commercial-milky white (CM) sago. The maximum and minimum mean diameter of the different grades of sago calculated by arithmetic and geometric mean methods was 5.88 mm and 5.66 mm for Nylon-pearl (NP) sago and 2.56 mm and 2.50 mm for Nylon-pearl (NP) sago, respectively. The data in the table revealed that the values of mean diameter of sago calculated by arithmetic mean method for different grades were very close to the geometric mean method. This may be due to the shape of the sago which approached a sphere both when it was before and after roasting/steaming too. The shape of sago is very important in terms of price and consumer acceptance at commercial level. Sphericity is an important property to describe the shape of sago. The sphericity of sago made by steaming process was less compared to sago made by roasting process. Sphericity was maximum (0.86) in the Commercial-best (CB) sago and was minimum (0.63) in the NP sago. This might be due to more volumetric changes in sago occurred in the heat treatments process done after globulation. The change in bulk density, particle density and porosity of different grades of sago is presented in Table 1. A maximum bulk density and particle density were

observed in CS sago and CM sago samples respectively. Similarly a maximum porosity (84.95%) was noticed in CB sago. The decrease in bulk density and increase in porosity with decrease in moisture content for minor millets was reported by [28]. Among the three important physical properties studied namely, bulk density, particle density and porosity, for a unit change in per cent moisture content, the highest percentage change was observed in porosity and least change was observed in particle density.

3.2 Functional Properties

The functional properties of the different grades of sago are shown in Table 2. From the analysis of data showed that there was a significant difference between swelling power in the roasted commercial and steamed nylon sago samples. The highest solubility (14.0%) in CM sago, while the lowest solubility (3.50%) in NC sago was noticed (Table 2).

The degree of gelatinization of starch directly affects solubility [29]. The highest swelling power (39.59 g/g) was found in NL sago, while the lowest value (7.77 g/g) was found in CS sago. The steaming process significantly increased the swelling power of sago in comparison with roasting process, which had little effect on swelling power of sago. This is probably due to a partial or complete gelatinization of the starch present in sago. During cooking, the sago observes water. The highest cooking time (12 min) and the lowest cooking loss (2.37%) were noticed in CS sago. It indicates that the gelatinization of sago starch after globulation followed by steaming accelerated the retrogradation to set the structure of sago [30,31] which corresponds to the reduction in cooking time. The functional properties (solubility index, swelling power, cooking time and cooking loss) of different grades of sago were also found to be statistically significant except oil absorption index. The oil absorption of sago is related mainly to the surface properties of the cassava starch molecules. The oil absorption index is affected by lipophillic nature of sago starch granule structure [32] and mostly influenced by presence of protein, which contains both hydrophilic and hydrophobic parts [33].

3.3 Pasting Properties

Pasting properties of the different grades of sago are presented in Table 3. The highest peak viscosity was noticed for roasted sago due to increase in granule rigidity and resistance to shear [34].

The viscogram of the different grades of sago paste are presented in Fig. 4. Peak viscosity of the different grades sago increased in the following order: CB>CM>NP. Comparing different grades of sago, we could found steamed nylon sago (NC) showed lowest peak (370 cP), trough (249 cP) and set back (90 cP) viscosities.

The decrease in setback viscosity indicating the lowering retrogradation rate of sago paste. The final cold paste viscosity (FV) is much higher in the roasted commercial (CB) sago. This could be due to increased retrogradation of the gel on cooling. There was a significant difference in disintegration rate (%) of different grades of sago. The disintegration rate (DR) of different grades of sago gel increased in the following order: CS>CB>CM.

Table 1. Physical properties of the different commercial grades of sago

Parameters	CS	CB	CM	NC	NP
Moisture content, % d.b	9.42±0.01^{d}	8.6±0.12^{bc}	7.59±0.03^{a}	8.65±0.01^{c}	8.38±0.02^{b}
Arithmetic mean diameter (mm)	4.11±0.11^{c}	3.80±0.21^{bc}	3.65±0.91^{b}	2.56±0.39^{a}	5.88±0.25^{d}
Geometric mean diameter (mm)	3.94±0.08^{d}	3.66±0.01^{c}	3.57±0.03^{b}	2.50±0.32^{a}	5.56±0.38^{e}
Sphericity	0.81±0.01^{c}	0.86±0.03^{d}	0.83±0.01^{cd}	0.70±0.0^{b}	0.63±0.04^{a}
Bulk density (kg m^{-3})	470±0.11^{e}	420±0.18^{a}	460±0.13^{d}	440±0.24^{c}	430±0.21^{b}
Particle density (kg m^{-3})	790±1.15^{b}	780±1.97^{a}	800±1.69^{c}	780±2.11^{a}	790±2.59^{b}
Porosity (%)	67.03±1.97^{a}	84.95±2.18^{c}	73.15±2.56^{b}	76.14±1.94^{b}	67.03±2.24^{a}

Mean ± standard deviation, n=3. Value with same letter in the same row is not significantly different at p≤0.05

Table 2. Functional properties of the different commercial grades of sago

Parameters	CS	CB	CM	NC	NP
Solubility index (%)	12.5±0.20^{b}	12.0±0.16^{b}	14.0±0.21^{d}	3.50±0.23^{a}	13.0±0.28^{c}
Swelling power (g/g)	7.77±0.14^{a}	8.29±0.16^{a}	13.75±0.13^{c}	9.23±0.15^{b}	39.59±0.35^{d}
Cooking time (min)	12.0±0.15^{d}	10.0±0.23^{c}	7.0±0.12^{b}	6.0±0.24^{a}	9.0±0.11^{c}
Cooking loss (%)	2.37±0.69^{a}	11.91±0.12^{bc}	17.97±0.14^{d}	10.32±0.46^{b}	12.69±0.24^{c}
Oil absorption index (g/g)	1.14±0.11^{a}	1.23±0.14^{b}	1.15±0.18^{a}	1.44±0.12^{c}	1.13±0.14^{a}

Mean ± standard deviation, n=3. Value with same letter in the same row is not significantly different at p≤0.05

Table 3. Pasting properties of different commercial grades of sago

Sample	PV (cP)	TV (cP)	BV (cP)	FV (cP)	SV (cP)	DR (%)	RR (%)	PT (°C)
CS	781±12^{b}	221±18^{a}	560±14^{c}	471±19^{b}	250±09^{b}	0.71±0.02^{e}	0.32±0.01^{b}	68.50±0.03^{b}
CB	2826±14^{e}	1529±17^{d}	1297±19^{e}	2240±21^{d}	711±13^{e}	0.45±0.03^{d}	0.25±0.04^{a}	61.75±0.04^{a}
CM	2481±10^{d}	1574±13^{e}	907±16^{d}	2263±16^{d}	689±10^{d}	0.36±0.0^{c}	0.27±0.02^{ab}	71.05±0.01^{c}
NS	370±8^{a}	249±12^{b}	121±11^{b}	339±19^{a}	90±11^{a}	0.32±0.02^{b}	0.24±0.03^{a}	69.12±0.06^{bc}
NL	922±16^{c}	871±6^{c}	51±2^{a}	1313±24^{c}	442±15^{c}	0.05±0.00^{a}	0.47±0.02$^{c68.52}$	69.95±0.02^{bc}

CS-Commercial-special, CB-Commercial -best, CM-Commercial-milky white, NS-Nylon -small, NL-Nylon- large
Mean ± standard deviation, n=3.
Value with same letter in the same column is not significantly different at p<0.05

However, the lowest disintegration rate was noticed (0.05 %) in NP sago due to formation of cohesive network. A negative correlation was obtained between the peak viscosity, swelling power and disintegration rate (%) of different grades of sago gel. Retrogradation is the process of realignment of amylose and amylopectin molecules structure following gelatinization occurs. It is used to describe changes in physical behavior of starch. The highest retrogradation rate (%) and pasting temperature were observed in NP and CM sago respectively. The increase in pasting temperature of sago could be due to strengthening of glycosidic bonds.

3.4 Dynamic Rheological Properties

The dynamic rheological properties *viz.* storage modulus ($G^{'}$), loss modulus ($G^{''}$), complex viscosity, complex modulus and phase angle (δ) of different grades of sago gels were determined over a frequency sweep of 0.1 to 10 Hz and the results are presented in Fig. 5.

The dynamic moduli involves two parameters *viz.* storage modulus ($G^{'}$) and loss modulus ($G^{''}$). In a dynamic oscillation test, the solid behavior of food is characterized by elastic or storage modulus (G') and the liquid behavior by the viscous or loss modulus ($G^{''}$). Among the different grades of sago, storage modulus was lowest in steamed nylon sago (NC). This might be due to the partially or completely gelatinized form of starch in sago enhanced the solid network of the steamed sago. The loss modulus ($G^{''}$) was higher than the storage modulus ($G^{'}$) of the different grades of sago. This indicated that the sago gels behaved like a dilute solution. This is also proved by higher phase angle values. This result was in agreement with [35,36]. The storage and loss modulus were increased with increase in frequency of the different grades of sago. The phase angle value was high for roasted commercial sago (CS) and the steamed nylon sago (NC) at frequency of 10 Hz. The lowest complex viscosity and complex modulus were noticed in the steamed nylon (NL) and NP sago.

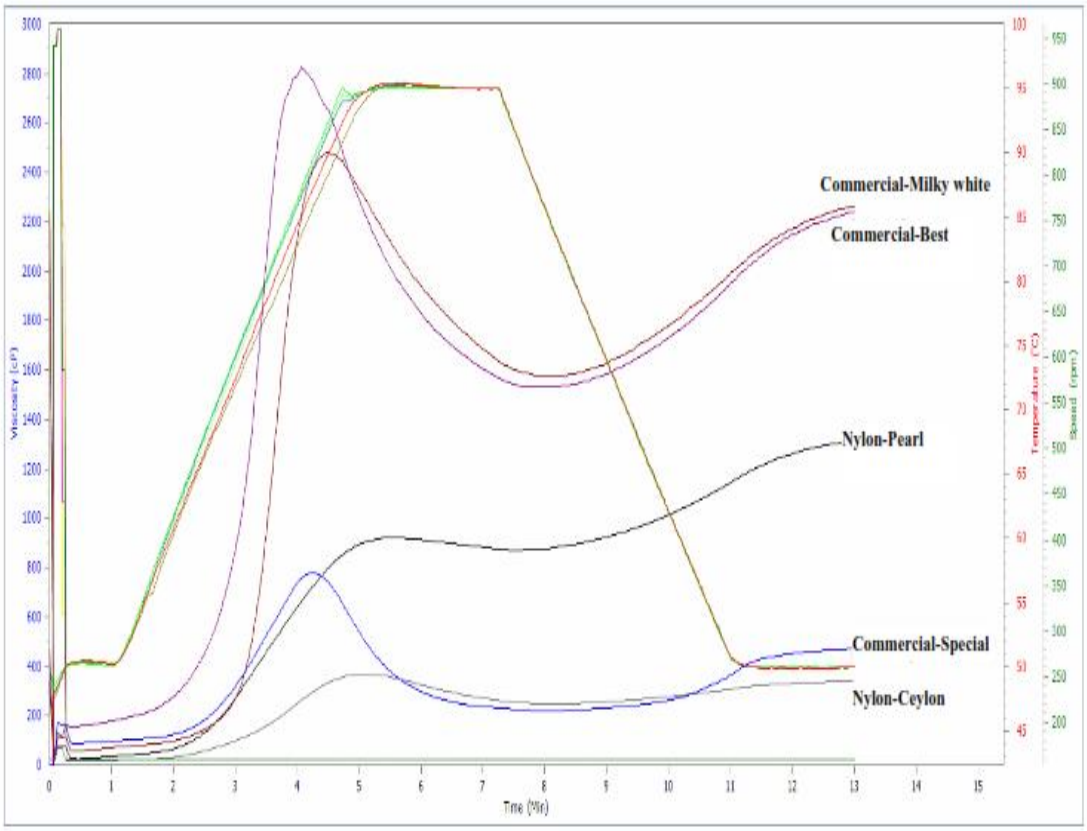

Fig. 4. Viscogram of sago gels in different commercial grades of sago

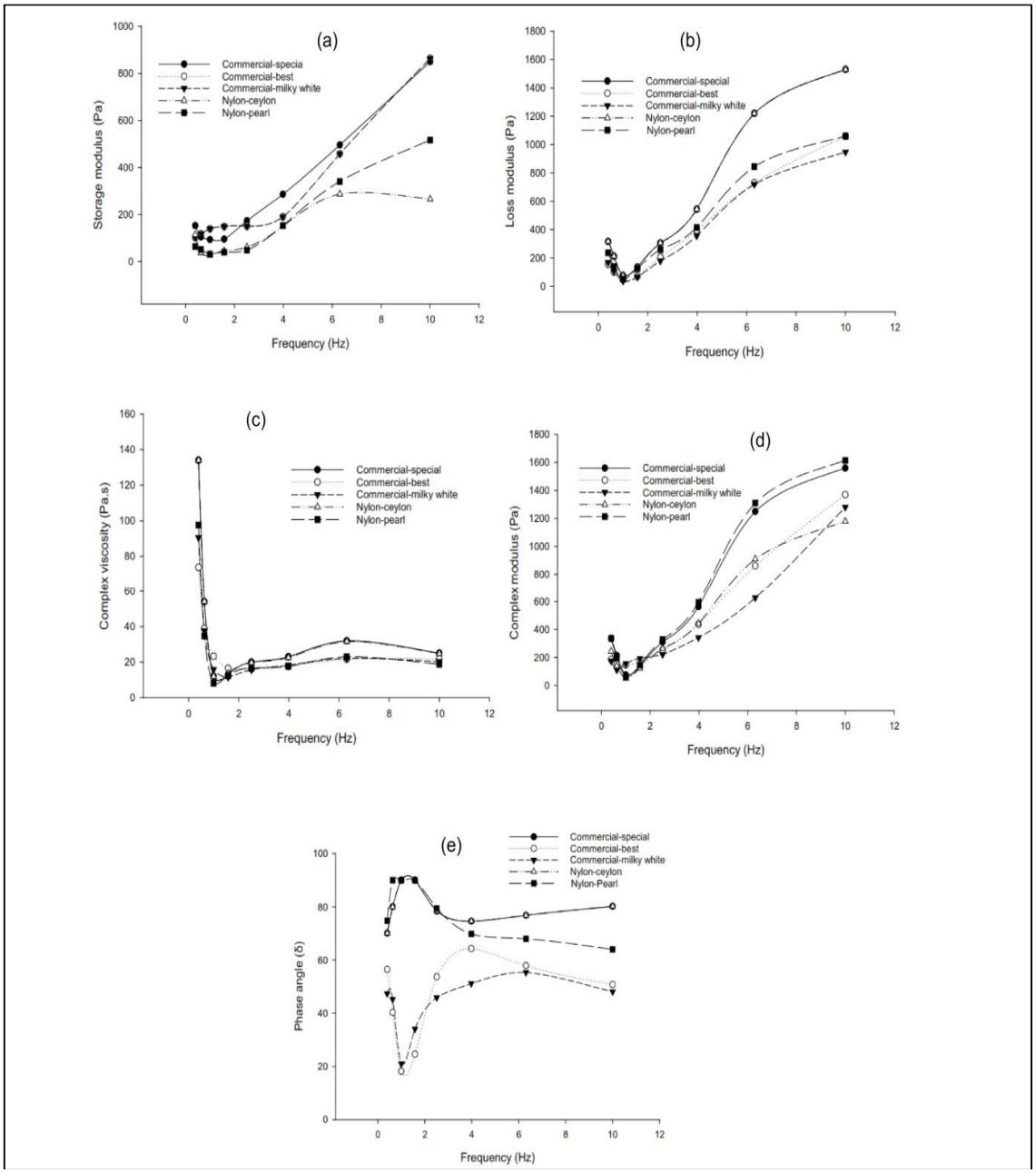

Fig. 5. Dynamic mechanical spectra of different commercial grades of sago (a-storage modulus, b-loss modulus, c-complex viscosity, d-complex modulus, e-phase angel)

4. CONCLUSION

The roasting and steaming treatments did cause significant effect on the various engineering properties of different commercial grades of sago. The information on physical properties (size, shape, density, porosity) of roasted and steamed sago is essential for designing mechanical dryer and other processing equipments. The maximum arithmetic and geometric mean diameter of the steamed nylon sago (NP) were 5.88 mm and 5.56 mm respectively at 8.38% d.b. For commercial consideration, the shape of sago is very important and it was determined by sphericity. The sphericity of roasted and steamed nylon sago varied from 0.81 to 0.86 and from 0.63 to 0.70, respectively. The true density of roasted

and steamed nylon sago varied from 780 to 800 kg m^{-3} and from 780 to 790 kg m^{-3}, respectively. The highest swelling power was noticed in the steamed nylon (39.59 g/g) sago, whereas the lowest was noticed in the roasted commercial (CS) sago. The lowest cooking loss was observed in the roasted commercial (CS) sago. The oil absorption index (g/g) was reported to be lowest in the steamed nylon (CS) sago as compared with roasted commercial sago. The trend of increase in peak viscosity with decrease in pasting temperature was observed. The different grades of sago gel behaved like a dilute solution due to increase in loss modulus over storage modulus.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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