Characterization of Physicochemical and Functional Properties of Starch from Five Yam (*Dioscorea Alata*) Cultivars in Indonesia

Lula Nadia, M. Aman Wirakartakusumah, Nuri Andarwulan, Eko Hari Purnomo, Hiroshi Koaze, and Takahiro Noda

***Abstract*—The research aim was to investigate yam starch physicochemical and functional characteristic. Five yam cultivars, yellow, orange, light purple, purple, and dark purple yams were used. SEM examination show three dimensions of starch granule which was round, oval and spherical in shapes. Particle size analysis performed asymmetrical unimoda distribution with 7 to 100 µm range of granule size. The relative crystallinity ranged 20.6 to 30.4% with B-type structure. The amylose and phosphorus content ranged 23.44 to 26.99% and 268 to 365 ppm respectively. These starch physicochemical characters lead to the gelatinization character To, Tp and ∆H ranged 73.9 to 77.4°C, 78.0 to 80.7°C, and 16.2 to 16.9J/g respectively. Pasting properties showed pasting T and peak viscosity ranged 81.95 to 86.38°C, 477.35 to 571.15RVU respectively. All the starches showed G' has higher value than G" up to ω=5(10)^5 rad/s frequency sweep. No intersection between G' and G" graphs were found in OY and PDY up to ω=10^7 rad/s, which indicated the strength and stable gel of both cold pasta.**

***Index Terms*—Crystallinity, gelatinization, size distribution, viscoelastisity, yam starch.**

I. Introduction

The needs of starch in food industry, closely related to the character formation of its paste that was adhesive, stable against heating and cooling [1]. As thickener, the paste can form a smooth gel and remain flexible in cold conditions, thus improve the viscosity, texture and mouth feel of processed products [2]. These functional properties of starch were influenced by its physicochemical character [3], [4]. The starch physicochemical characteristic was influenced by several factors such as the type (source) of starch [5], amylose and amylopectin ratio, and starch gelatinization [6]. Starch from different cultivars showed amylose content, gelatinization, granule morphology and starch crystallization different from each other [5], [6].

On the application of starch in food processing, starch characteristics such as gelation, solubility, retrogradation (recrystallization), thermal character and its viscoelastisity is very important information. So that, it make appropriate usage of the starch in order to improve the quality of processed food as expected. The starch functions, whether forming pastes, adhesives, thickeners, emulsifiers, fillers are associated with it physicochemical and functional character [7]. Besides, the use of natural starch with applicative character in the food industry is in great demand. Some researchers have found that yam starch paste have high viscosity with stable gel character against heating and storage as the potential advantages of this starch to be applied in food industry [8]-[10]. Therefore, the purpose of the research was to investigate the characteristic of physicochemical and functional properties of tuber starch from five yam cultivars.

II. Materials and Methods

A. Material

Yam tubers obtained from yam plan cultivation in Kulon Progo, DIY, Central Java. There were five cultivars named 'uwi wayang' (Yellow yam/YY), 'uwi koneng' (Orange yam/OY), 'bang kulit' (Light purple yam/LPY), 'punuk banteng' (Purple yam/PY), 'rondo seluku' (Dark purple yam/DPY). The tuber harvested after the stem withered which proximately 12 months of planting, as the bulb assumed to be maximum in growth size and starch content.

B. Methods

Starch obtained using method developed by Riley *et al.* [11] with modifications. The tuber bulbs that have been peeled, cleaned, and thinly sliced (2 to 3 mm thick). To remove mucus, tuber slices soaked in 15% NaCl for 60 minutes and washed again. Tuber slices then smoothed by commercial blender. The slurry then extracted using extractor with 100 mesh filter in it. Suspension obtained was precipitated overnight, precipitated starch, and then dried in an oven at temperature 50±5°C for 8 hours. Dry starch then mashed with a mortar, sealed packaged and stored at -25±5 °C.

The physical characteristics include: starch granule morphology observed by Polarized Light Microscope (PLM) and Scanning Electron Microscope (SEM); starch granule size distribution was determined using Sympatec Helos (H1169) & Rodos *Particle Size Analyzer*; Type crystallites

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and relative crystallinity observed by X-ray deffractometer XRD 7000 Maxima, Shimadzu; Gelatinization characteristics (initial temperature, peak temperature, and enthalpy) observed by Differential Scanning Calorimetry (DSC 6100 Sample PC EXSTAR reference to Seiko Instruments Inc. 6000) according to Noda *et al.* [12].

The analysis of the chemical characteristic includes proximate analysis: moisture, lipid, protein, and ash [13]. Blue Value at 680 nm was determined according to Noda et al. [14] using intact starch rather than defatted starch. Amylose content was determined from Blue Value according to the equation of Takeda *et al.* [15]. The BVs of amylose and amylopectin isolated from YS of 1.55 and 0.168, respectively, were determined by Suzuki *et al.* [16]. These BVs were used in the calculation of the amylose content of yam starch. Total phosphorus content was done using methods developed by Riley *et al.* [11] with modifications.

Pasting characteristics (paste temperature, peak viscosity, final viscosity, breakdown viscosity and setback viscosity) were determined as described previously [12]. Starch samples were also added to 25 ml of distilled water to prepare 8% suspension on a dry weight basis (w/v). Each suspension was kept at 50 ℃ for 1 min and then heated up to 95 ℃ at 12.2 ℃/min and held for 2.5 min at 95 ℃. It was then cooled to 50 ℃ at 11.8 ℃/min and kept for 2 min at 50 ℃. Viscoelastisity was measured with Rheometrics's Dynamic Analyzer RDA II, equipped with 25 mm radius steel cone plate. A 4% gelatinized starch solution was placed in a gap of 65 μm and frequency sweep test was run from 10^4 to 10^7 rad/s at 25 ℃ for 3% strain [17].

C. Statistical Analysis

Analysis of variance was conducted to determine the influence of cultivar on the physicochemical properties at 95% confidence level, with a completely randomized design. Data analysis was performed with SPSS 20.

III. Results and Discussion

Starch extraction was easily done on a laboratory scale, but a fairly high content of mucilage from the tuber, made the starch extraction in a larger scale become complicate. Thus starch yield can be obtained only up to 7 to 16% wb of tuber (from 17 to 35% total starch content of wb tuber). This result was much higher than that obtained by previous researcher that only 4% wb of tuber [18].

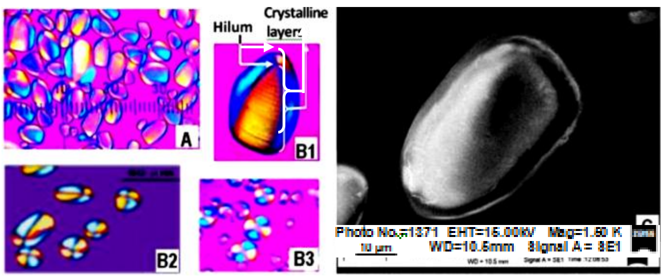

Fig. 1. Starch morphology A=Birefringence 400x magnitudes PLM; B1=Yam hilum position, B2=Potato starch granule [20], B3=Tapioca starch granule; C=SEM micrograph 1500x magnitudes.

A. Starch Granule Morphology

Based on polarized light microscopy, starch granules from five yam cultivars exhibit birefringence pattern in nature (Fig. 1A). Birefringence pattern was seen as two crossing bands which called Maltese cross [19]. There was also a degree of molecular order seen as semi-crystalline layers that arranged radials. It also shows hilum and growth patterns with increasing diameter ring coating granules, which stems from the hilum (Fig. 1B1).

According to Jane [21] the growth pattern was influenced by genetic and environmental factors through amylopectin biosynthesis to form granule morphology architectural. Different from tapioca starch (Fig. 1B3), yam starch hilum positions was located at the edge of the granules, similar to the potato starch hilum position (Fig. 1B2) [22], [11]. Birefringence patterns on starch showed molecular order and composition of starch. Strong birefringence pattern indicated to high structural regularity of the amylopectin, whereas weak contrast back grown of birefringence showed that the starch had higher amylose content [23] that can be seen in yam (Fig. 1A).

Smooth wavy surface and three dimensions shape of starch granules (Fig. 1C) can be observed by using SEM. From the micrograph showed that yam starch granule has little thick, wide and long, and from both microscope observations showed that the starch granules have a round, oval, ellipse and few with spherical shape (Fig. 1A and 1C). Starch granule morphology was consistent with previous observations on yam starch [8]-[11], [24]. Sujka and Jamroz [25] found that the starch with finely granular surface indicates that in naturally, the starch not easy to chemically reacted, as also found in the yam starch that has smooth and fine surface.

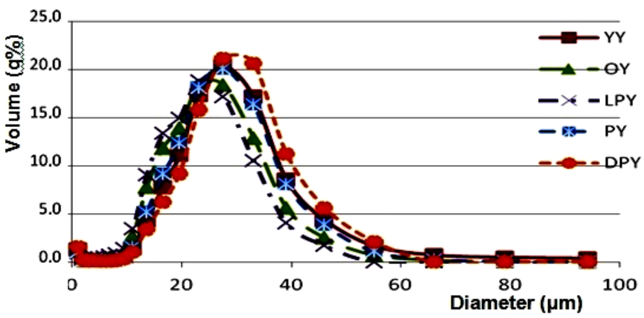

Fig. 2. Starch granule size from five yam cultivars.

TABLE I: Granule Size Distribution

Starch sample	Size distribution (µm)	Mean of granule size
YY	6 – 90	27.93 ± 0.11[c]
OY	9 – 100	28.78 ± 0.13[b]
LPY	7 – 66	21.51 ± 0.08[e]
PY	10 – 80	25.06 ± 0.06[d]
DPY	11 – 80	32.00 ± 0.11[a]
Tapioca*	8 – 24	15.90
Potato**	8 – 131	47.90

Value with the same alphabet in one column showed no significant difference (p<0.05),*Peroni *et al.* [8], **Puncha-arnon *et al.* [26].

The average value of granule size ranged from 21.51 to 32.00 μm with asymmetric unimoda distribution (Table I). The distribution of the granules has a high proportion on the larger size (Fig. 2). The average value of granule size of each yam cultivar, from the smallest was LPY, PY, YY, OY and DPY. The starch granule size distribution was in the size range found by Riley *et al.* [11], Peroni *et al.* [8], and Yeh *et al.* [24]. The yam granule size range was larger than tapioca starch (μ = 15μm with a range from 7.1 to 25.0 lm) [22] and similar to potato starch (μ = 30 μm with a range of 5 to 100 μm) [27].

Based on the morphology and granule size, yam starch granule was closely related to potato starch. While on size distribution, yam has unique distribution pattern which different from tapioca and potato that tend to have symmetrical distribution [28]. Meanwhile, the hilum position might be attributed to the biological origin and plant physiology which is specific for each species [29]. The position of hilum might influence the crystalline disruption patterns during starch gelatinization [30].

B. Chemical Compound

Based on total levels of amylose content (Table II), yam starch has ranged between 24.31 to 26.99%. This result was in range (20 to 30%) found by Tester *et al.* [31] and Waduge *et al.* [32]. In relation to the starch group, yam belongs to the group with moderate to high amylose content [9], [33]. There was no difference between LPY and PY starches (p<0.05). DPY and OY starches obtained significantly high and low amylose content (p<0.05). According to Thomas and Atwell [34] when the starch amylose content less than 30%, it can be assumed that the amylopectin content more than 70%. Then, the ratio of amylose to amylopectin was higher in yam than in potato starch and tapioca.

TABLE II: PROXIMATE, AMYLOSE AND PHOSPHORUS CONTENT IN FIVE YAM STARCHES

Starch sample	Moisture (%)	Lipid (% DB)	Protein (% DB)	Ash (% DB)
YY	12.99 ± 0.01^{b}	0.30 ± 0.01^{a}	0.031 ± 0.0062^{a}	0.30 ± 0.011^{c}
OY	13.51 ± 0.03^{a}	0.25 ± 0.03^{c}	0.028 ± 0.0002^{c}	0.66 ± 0.017^{b}
LPY	12.00 ± 0.02^{c}	0.16 ± 0.01^{d}	0.019 ± 0.0007^{e}	0.24 ± 0.026^{e}
PY	12.69 ± 0.02^{b}	0.30 ± 0.03^{a}	0.030 ± 0.0011^{b}	0.91 ± 0.009^{a}
DPY	11.48 ± 0.03^{d}	0.27 ± 0.02^{b}	0.027 ± 0.0031^{d}	0.26 ± 0.020^{d}
Tapioca*	-	0.15	0.020	0.21
Potato**	-	-	0.030	0.27

Starch sample	Amylose (% DB)	Amylopectin (% DB)***	Ratio Am/Ap	Phosphor ppm (DB)
YY	25.88 ± 0.23^{b}	70.00 ± 0.23^{b}	0.37	310.69 ± 0.95^{c}
OY	24.51 ± 0.32^{cd}	69.76 ± 0.32^{cd}	0.35	335.36 ± 1.64^{b}
LPY	24.31 ± 0.38^{d}	73.69 ± 0.38^{a}	0.33	268.15 ± 0.94^{e}
PY	24.58 ± 0.67^{c}	69.30 ± 0.67^{d}	0.35	291.00 ± 1.64^{d}
DPY	26.99 ± 0.85^{a}	69.93 ± 0.85^{c}	0.39	361.07 ± 0.93^{a}
Tapioca*	19.8	79.82	0.25	70
Potato**	16.8	82.90	0.20	583

Value with the same alphabet in one column showed no significant difference (p<0.05), DB = dry basis, *Peroni *et al.* [8], **Puncha-arnon *et al.* [26], ***By difference.

Lipid in yam starch was ranged 0.16 to 0.30% db (Table I), while protein ranged 0.019 to 0.031% db (Table I). It was reported that protein in starch was present as minor component mainly in granule cell wall, while lipid was in internal component of starch [35]. Comparing to potato and cassava, yam starch has the highest level of lipid content and about the same level of protein content. The present of lipid and protein in starch was effect on starch pasting and gelatinization properties [36].

It was also obtained that total phosphorus content of yam starch has a range from 268.15 to 361.07 ppm db (Table I), sequentially from the lowest LPY, PY, YY, DPY and OY. The phosphorus levels were significantly different for each cultivar and DPY starch has the highest phosphorus levels (p <0.05). The value range was higher than that reported by Riley *et al.* [11], Peroni *et al.* [8], and Baah [10] but relatively lower than those obtained by Jayakody *et al.* [9]. Sajilata and Singhal [37] reported that starch with a high level of phosphorus content can improve film forming, while the starch with a high level of amylose content has strong gel. Starch with the strong gel character was suitable for products that were processed with high temperature.

The presence of phosphorus leads to a brightness pasta, pasta consistency viscosity and stability [38]. The phosphorus in starch tubers are in the form of phosphate-monoester which covalently bonded to C3 or C6 of amylopectin glucose monomers in branch chain-B longer chain [39], [40]. Thus, the higher the ratio of amylose/amylopectin means the lower of amylopectin and consequently lower phosphorus content of the starch of yam than potato. The higher yam phosphorus content in yam than in tapioca was due to the different of crystalline type, whereas tapioca with type-A crystallite which has shorter amylopectin branch chain than type-B crystallite [21].

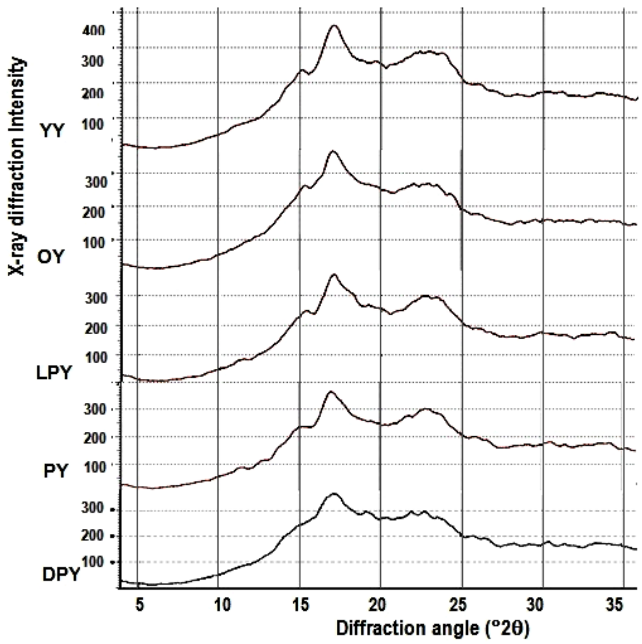

Fig. 3. X-ray diffraction of starch from five yam cultivars.

C. Crystallinity

From the X-ray diffraction, the yam starch semi-crystalline has type-B pattern, which indicated with the existence of peak refraction intensity at 16.94°θ to 17.22°θ (Fig. 3). This crystal type was slightly different from that found by Riley *et al.* [11] and Huang [41] which has small peak refraction intensity at 5°θ refraction. However, this finding consistent with X-ray diffraction patterns of Sri Lanka yam 'Hingurala' [9] and Jamaica yam 'Renta Yam' [11]. This can occur due to the differences in yam cultivars observed. Based on relative crystallinity of starch, it was found that LPY starch significantly has the highest value ($p<0.05$), while DPY has the lowest value (Table III).

The crystalline structure indicates the absence of organized helices into well-defined three-dimensional structures of starch [31]. It is strongly influence by the chain length of the amylose and amylopectin content and the arrangement of the double helices chains [31], [42], [43]. The different with the type-A pattern was based on the chain length of amylopectin. According to Hizukuri [42], in type-A crystalline pattern, the amylopectin consist of higher portion of short chain (below DP 19), while in type-B crystalline pattern, the amylopectin consist of higher portion of longer chain (DP = 20 to 37).

TABLE III: CRYSTAL TYPE AND CRYSTALLINITY

Starch sample	Type of crystal	Relative crystallinity (%)
YY	B	24.3 ± 0.3^{d}
OY	B	23.8 ± 0.1^{e}
LPY	B	28.4 ± 0.5^{c}
PY	B	24.5 ± 0.4^{d}
DPY	B	20.6 ± 0.1^{f}
Tapioca*	A	37.0 ± 0.5^{a}
Potato*	B	30.0 ± 0.4^{b}

Value with the same alphabet in one column showed no significant difference ($p<0.05$), *Gunaratne and Hoover [5].

The starch relative crystallinity showed the crystalline packing which consist mostly of amylopectin with double helices arrangement of it branch chains and the adjacent amylopectin double helices within crystalline lamella. From previous study indicated that the higher the relative crystallinity of the starch the higher the ordered arrangement, the closer package and the denser the amylopectin branch chain [42], [43]. The loose pack or less ordered branch chains and the amylose and amylopectin branch chains which occupy the amorphous region lead to the bigger size of this region and caused the relative crystallinity become lower in DPY starch.

TABLE IV: GELATINIZATION CHARACTER PARAMETER

Starch sampel	T_o (°C)	T_p (°C)	ΔH (J/g)	ΔT(°C)
YY	75.5 ± 0.4^{c}	79.0 ± 0.3^{b}	16.7 ± 0.1^{a}	11.6 ± 0.354^{c}
OY	73.9 ± 0.1^{d}	79.0 ± 0.1^{b}	16.9 ± 0.0^{a}	16.1 ± 0.141^{a}
LPY	76.2 ± 0.1^{b}	80.5 ± 0.1^{a}	16.3 ± 0.0^{b}	12.8 ± 0.212^{b}
PY	77.4 ± 0.2^{a}	80.7 ± 0.1^{a}	16.2 ± 0.2^{b}	9.7 ± 0.212^{d}
DPY	73.9 ± 0.1^{d}	78.0 ± 0.0^{c}	16.3 ± 0.1^{b}	9.1 ± 0.141^{e}
Tapioca*	61.6.	66.7	10.4	11.39
Potato**	62.0	65.8	17.2	10.00

Value with the same alphabet in one column showed no significant difference ($p<0.05$), *Peroni *et al.* [8], **Puncha-arnon *et al.* [26].

D. Gelatinization

DSC observation showed that the peak temperature (Tp) from the lowest value was DPY, OY ~ YY, LPY and PY (Fig. 4). Range of gelatinization parameter values obtained corresponds to that obtained by previous researchers [8], [9], [11], [44]. PY has the highest initial starch gelatinization temperature (To) and peak gelatinization temperature (Tp). While for the enthalpy value (ΔH), OY has the highest (Table IV). Compared with tapioca starch gelatinization, yam has parameter value higher, and with potato, yam has higher value of To and Tp but has the same enthalpy value.

Gelatinization is an irreversible change of starch by the excess of water in certain ranged of high temperature. It is a phenomenon which described by the disruption of molecular orders within the granule (breaking of H-bonds), granular swelling, crystallite melting, birefringence loss, starch solubilization and viscosity development [36]. The process started from the amorphous region with the diffusion of water, hydration and swelling of the starch granule. The uptake of heat leads to the loss of crystalline order, loss of optical birefringence, uncoiling and dissociation of double helices and amylose leaching [36].

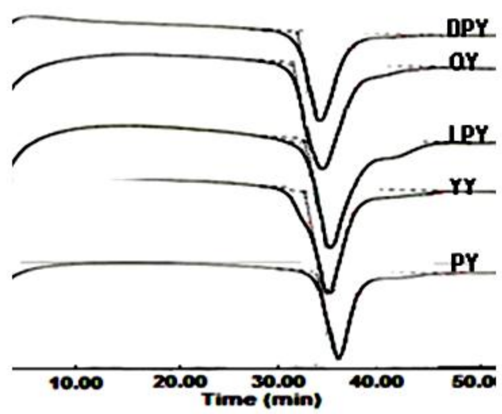

Fig. 4. Starch gelatinization from five yam cultivars.

The difference in gelatinization parameters value among the yam cultivar was due to the differences of physicochemical character of starch and crystallinity. The higher relative crystallinity and higher content of lipid complexes amylose chain will decrease hydration in the amorphous region, thus causing the higher thermal energy needed for melting the starch crystallite [45]-[46]. This seems to be reasonable since the starches have the same amylopectin branch chain length distribution [45].

The same enthalpy value of LPY, PY and DPY means that to form gel the starches require the same total energy. In this case, even though LPY starch has higher crystallinity which can lead to higher ΔH value, but it has the lowest lipid content from two others. The ΔH value also indicates a stronger crystal structure of OY and YY starch. This suggested that the denser packed of higher order amylopectin branched chain [45] might contribute to the higher energy needed in melting the crystallite region of the starches.

The lower ΔH value in yam then the potato starch, suggested weaker interaction between adjacent amylopectin double helices within crystalline lamella. Although tapioca has higher crystallinity but the different in type of crystalline profile could lead to the lower ΔH value of tapioca starch whereas type-A has higher portion of short chain of amylopectin branch. Moreover, tapioca starch has no protein and small amount of lipid which can contribute to the lower ΔH [46]-[48].

E. Pasting Characteristic

This character showed paste viscosity behavior during heating and cooling process with controlled stirring [49]. From Fig. 5, it was found that yam starch has a high peak viscosity during heating (95°C), and then rose again on cooling (95-50°C) until the final viscosity above 688 RVU, as found by Chen [50]. Table V showed that DPY starch had the highest peak viscosity and LPY had the lowest. Likewise, hot paste viscosity, DPY starch has the highest value. It was also obtained that, relative breakdown viscosity (to the peak viscosity) for YY, OY LPY, PY, and DPY were 25.1%, 24.7%, 23.3%, 20.4%, and 17.9% respectively. As obtained by Amani et al. [51] yam natural starch paste has a clear, stable and slow syneresis during cooling as well as resistant to stirring.

TABLE V: PASTING PARAMETER FROM FIVE YAM CULTIVARS

Starch sample	Peak V. (RVU)	Hot paste V. (RVU)	Breakdown V. (RVU)	Setback V. (RVU)	Final V. (RVU)	T paste (°C)	Peak t (mnt)
YY	481.82 $\pm$ 0.10^{d}	360.89 $\pm$ 2.83^{d}	120.93 $\pm$ 0.42^{b}	335.51 $\pm$ 0.60^{c}	696.40 $\pm$ 0.21^{d}	83.95 $\pm$ 0.00^{c}	4.90 $\pm$ 0.04^{d}
OY	527.63 $\pm$ 0.42^{b}	397.35 $\pm$ 0.69^{b}	130.28 $\pm$ 0.13^{a}	338.20 $\pm$ 0.04^{b}	735.55 $\pm$ 0.18^{b}	84.78 $\pm$ 0.04^{b}	5.10 $\pm$ 0.04^{b}
LPY	477.35 $\pm$ 0.02^{e}	366.21 $\pm$ 0.95^{d}	111.14 $\pm$ 0.91^{c}	372.59 $\pm$ 0.71^{a}	738.80 $\pm$ 0.06^{a}	86.38 $\pm$ 0.04^{a}	5.24 $\pm$ 0.05^{a}
PY	490.99 $\pm$ 0.22^{c}	390.86 $\pm$ 0.50^{c}	100.13 $\pm$ 0.07^{d}	317.74 $\pm$ 0.62^{d}	708.60 $\pm$ 0.03^{c}	84.78 $\pm$ 0.04^{b}	5.00 $\pm$ 0.00^{c}
DPY	571.15 $\pm$ 0.33^{a}	469.91 $\pm$ 0.73^{a}	102.24 $\pm$ 0.09^{d}	218.37 $\pm$ 0.57^{e}	688.28 $\pm$ 0.04^{e}	81.95 $\pm$ 0.57^{d}	4.90 $\pm$ 0.04^{d}

Value with the same alphabet in one column showed no significant difference (p<0.05), RVU= Rapid Visco Unit, V= viscosity, T= Temperature, t= Time

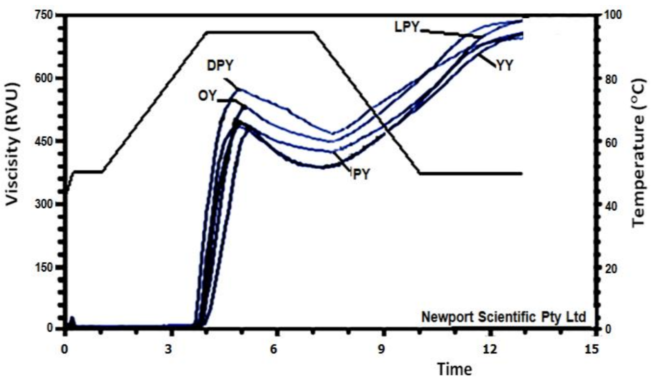

Fig. 5. Pasting character of starch from five yam cultivars.

The value of relative setback viscosity (to the hot pasta viscosity) in a row for YY, OY LPY, PY, and DPY were 92.9%, 85.1%, 101.7%, 81.3%, and 44.6% respectively. Compared other yam starch, LPY starch requires higher temperatures for pasting (86.38°C) and has higher final viscosity. The high value of LPY starch final viscosity (738.8 RVU), thought to be caused by more amount of smaller size (with higher uniformity) of LPY granule occupied the volume, the granule integrity by the phosphorous content in the crystalline region and also amylose re-association of the starch that all together make stronger gel when the pasta is in cooling stage.

The low relative breakdown viscosity of DPY showed stability of the starch hot paste, as a result of the granule stability during heating and stirring [52]. This indicates that only small portion of amylose can lyses from the granule and the stronger internal binding in DPY starch granules enhance the granule integrity. The lowest relative setback viscosity of DPY starch indicated that the starch has low tendency of retrogradation, and vice versa on LPY starch. The highest phosphorous content in crystalline region of DPY may depress lipid to the amorphous region and caused more amylose-lipid complex and reduce free amylose amount that can lyses. Amylose lyses resulting in forming amylose intermolecular re-association, performing network in setback viscosity and generate retrogradation [53].

Retrogradation or syneresis of the starch implies appearance of separate fluid droplets on starch gels which caused by water molecule release trough the re-association of amylose chains [53]. The higher retrogradation tendency leads to easily staling in bread and rapidly precipitation and loss of viscosity in sauce. Thus, in food processing the lower the relative setback value the more preferable character of the starch paste. On the other hand, the higher setback value of starch is needed in making non-wheat noodles [54] such as in LPY starch. Furthermore, the lower setback value lower retrogradation tendency of which starch is needed in bread making in order to reduce bread staling [55].

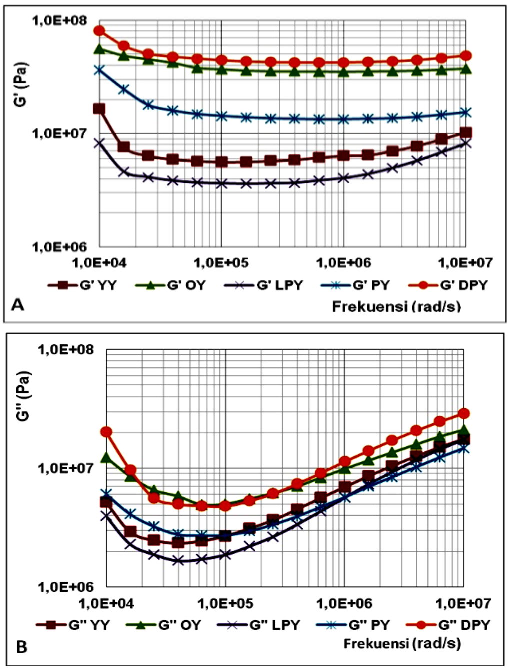

Fig. 6. Viscoelastisity of starch cold pasta profile, (A) storage modulus (G') and (B) loss modulus (G") from five yam cultivars with sweep frequency.

F. Paste Viscoelastisity

The starch paste (4% gelatinized starch solution) showed unique viscoelastisity caracter which remain stable in high sweep frequency up to 10^{4}-10^{7} rad/s. Fig. 6 showed the value of G' (storage modulus) were relatively stable for all starches, from the lowest LPY, YY, PY, OY and DPY. While the value of G" (loss modulus) showed that OY and DPY are higher than PY, YY and LPY, and the value of G" increases with increasing frequency.

It was found that the G' has higher value than G" up to $5(10)^5$ rad/s frequency sweep for all the starches. The intersection between G' and G" graphs occurs at a frequency of $5(10^5)$ rad/s for LPY, $8(10^5)$ rad/s for YY, and 10^7 rad/s for PY. While the intersection between the graphs G' and G" for OY and DPY were not obtained until the frequency sweep reach 10^7 rad/s. At lower frequencies than the transition frequency, the starch paste was in elastic profile and above the transition frequency the paste was in viscous profile. The value of G' and G" were high in DPY and OY, and the intersection between G' and G" was not found until the frequency sweep reach 10^7 rad/s. This cold paste profile showed the strength and stable gel of both paste during frequency treatment. It is not easy to compare to other results in dynamic rheometry, due to the difference of sample concentration, rheometer equipment and temperature setting.

IV. Conclusion

Overall chemical compositions of starches were specific for each yam cultivar which affects the physical and functional properties of the starch. It can be concluded that the yam starch granule has uneven unimoda distribution with higher portion on the large granule size, with size range 7 to 100 µm. Granule disk shape was round, ellipse, oval and spherical with a smooth wavy surface. The chemical composition of yam starch has lipid content ranged from 16 to 30% db, amylose ranged from 23.4 to 26.99% db and phosphorus ranged from 268.15 to 365.36 ppm. db. Yam starch crystallinity structure has a pattern of type-B with a relatively low relative crystallinity which ranged from 20.6 to 30.4%.

With a relatively low retrogradation tendency, DPY starch cold paste has a high thickener capacity and strong gel profile against shearing and stirring, make it remains smooth and pliable in cold conditions. For these characters of starch, DPY might have more potential usage as stabilizer in cold food product, and as thickener in higher temperature processing product than other yam starches. Besides, with higher crystallinity and setback viscosity, the LPY starch might have potential usage for pasta making.

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