The Color, Water and Oil Holding Properties and Pasting Viscosities of Arrow Root (*Maranta arundinacea L*) Flour From Different Accessions and Irradiation Doses

Enny Sholichah[1*], *Radita* Suryana[2], *Puspita* Deswina[3], *Nana Sutisna* Achyadi[2], and *Achmat* Sarifudin[1]

[1]Research Center for Appropriate Technology, National Research and Innovation Agency (PRTTG-BRIN), Jl. K.S. Tubun No. 5 Subang 41213, West Java, Indonesia.
[2]Department of Food Technology, Pasundan University, Jl. Dr. Setiabudhi No.193, Gegerkalong, Sukasari, Kota Bandung, West Java, Indonesia 40153
[3]Research Center for Horticultural and Estate Crops, National Research and Innovation Agency (PRHB-BRIN), Jl. Raya Bogor Km 46 Cibinong, Bogor, West Java, Indonesia

Abstract. Gamma irradiation has been widely used as green method to induce mutations of arrow root plants; therefore, superior cultivars might be obtained. This research was purposed to evaluate the effect of different accessions (a1 (Pulosari – Pandeglang), a2 (Cicadas – Pandeglang), a3 (Cikondang – Pandeglang), a4 (Tamansari – Yogyakarta) and a5 (MN1 – Bogor)) and irradiation doses (b1(0 Gy), b2 (10 Gy), b3 (20 Gy), b4 (30 Gy), b5 (40 Gy) and b6 (50 Gy) on the properties of arrow root flour produced from irradiated arrowroot plants including color, water and oil holding capacities and also pasting viscosities. Results showed that gamma irradiation on the arrow root plants impacted the color properties of arrow root flour in which higher irradiation dose tended to produce brighter arrow root flour. Higher irradiation dose showed a tendency to produce arrow root flour with low water holding capacity but high oil holding capacity. Irradiation doses did not significantly impact all pasting viscosities (peak viscosity, final viscosity and set back viscosity). Keywords: arrow root, accessions, flour, gamma irradiation, dose.

1 Introduction

Indonesia is blessed with the most abundant natural resources of tubers such as potatoes, sweet potatoes, taros, canna tubers and arrow roots [1]. Arrow root tuber growth well in tropical climates. Eventhough peoples have known that arrow root is an edible source of food since long time ago just like cassava and sweet potato tubers. However, it has not been intensively cultivated in Indonesia. Most of Indonesian consume rice as its staple food,

[1]* Corresponding author: enny.sh002@gmail.com

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therefore, the utilization of other tubers including arrow root is limited. In order to enhance the use ability and shelf life of arrow root, the tuber should be processed to become flour [2].

Arrowroot usually is cultivated by a vegetative method in which a new plant grows from its rhizome [3]. In terms of plant propagation, the vegetative method produces new plants which are similar to their parent's gen. Therefore, it is difficult to increase the genetic heterogeneity of the plant particularly to find a new breed with superior characteristics [4]. One method to increase the heterogeneity of plant gen is by mutation inductions triggered by gamma irradiation. Reports say that plant breeding by irradiation techniques can expand the plant's genetic diversity. Ahloowalia and Maluszynski [5] summarized that the physical mutagens such as α, β, and γ rays and also chemical mutagens (Ethyl Methane Sulfonate, Diethyl Sulfate, Ethyl Amin, and Colchicine) have been widely used to induce the variation of plant's gen.

Gamma ray irradiation has been widely applied in an effort to obtain superior cultivars [6]. Mutations that occur in the direction of positive traits and are passed on to the next generation are mutations desired by plant breeders [6]. According to [7] mutagen materials are able to increase the frequency of mutations in a short time in order to obtain more diverse genetic variations, especially plants that are propagated vegetatively. The expansion of the genetic diversity of arrowroot will facilitate breeding so that the goal of improving quality and production can be achieved by producing new superior clones.

In plant breeding, the amount of dose used depends on the type of plant to be used. Determination of the appropriate irradiation dose is known based on radiosensitivity which is the sensitivity level of plants to irradiation treatment. Radiosensitivity can be estimated through the physiological response of the irradiated plant which should be lower than the dose that causes death to the plant (lethal dose) [8].

According to Roberts [9], radiation dose is the most critical factor in gamma irradiation. Each type of sample required a special dose to obtain the desired results. If radiation is less than the required dose, the desired effect will not be achieved. On the other hand, if the dose is excessive, the sample may be damaged. For instance dose to disinfect dried and cured fish, spices, and raw materials 0.15 kGy, to inhibit onions, garlic and potato tubers sprouting is 0.1 kGy, and to inhibit bananas, strawberries, mango and papaya ripening need 1 kGy. Thus, the amount of iradiation dose used depends on the type of material and the purpose of radiation.

Report says that gamma irradiation treatment has ability to increase the water content of cassava [10]. The starch content of irradiated cassava also increased from 40.41% to 45.74%. Moreover, irradiation treatment doesn't give significant effect on ash content but increased amylose content in cassava from 3.98% to 5.14%, which means the ratio of amylose and amylopectin of cassava is changed [11].

Currently, there is no report was found particularly the effect of accesions and irradiation dose on the physical properties of arrow root flour. Therefore, the aim of the research is to study the effect of different accesions of arrow root plant and irradiation dose on the physical properties of arrow root flour specifically the color, water and oil holding properties and pasting viscosities.

2 Material and methods

2.1 Material

The main raw material used in this study was arrow root flour which was obtained from five accessions. The arrow root tuber was obtained from irradiated arrow root plants which were irradiated with their respective doses of 0-50 Gy.

2.2 Sample preparation

The arrow root flour was processed from the arrow root tuber which was obtained from irradiated arrow root plants and the irradiation were done at six levels. Details of sample are explained in the experimental design section. The arrow root flour was produced by method of Nogueira [12] with slight modifications. Arrowroot rhizomes were peeled, washed with piped water, soaked in sodium metabisulphites solutions 1000 ppm for 15 minutes and sliced. Then, it was ground and sieved with a sieve of an aperture size of 150 µm. All treatments were carried out in triplicate. Prior to analysis, samples were packed in pastic bags and stored at room temperature.

2.3 Color properties

Color properties of samples were determined by using a colorimeter 3NH (Shenzhen ThreeNH Technology Co., Ltd., Shenzhen, China) according to the method of [13]. The color parameters including L*, a*, and b* were reported .

2.4 Water and Oil Holding Capacity

Water Holding Capacity and Oil Holding Capacity of samples were analyzed by using a modifed method of Sathe and Salunkhe [14] in which the amount of sample were adjusted.

2.5 Pasting vicosities

The pasting viscosities of samples were assayed by using Rapid Visco Analyzer (RVA-TecMaster, PerkinElmer, USA) following the method of Sholichah, Deswina, Sarifudin, Andriansyah and Rahman [15]. Three pasting viscosities parameters incuding peak viscosity, final viscosity and set-back viscosity were reported.

2.6 Experimental design

A Completely Random Design Group consisting of 2 factors including 5 accessions (a1 (Pulosari - Pandeglang), a2 (Cicadas - Pandeglang), a3 (Cikondang - Pandeglang), a4 (Tamansari - Yogyakarta), a5 (MN1 - Bogor)) and 6 levels of irradiation doses (b1 = 0 Gy, b2 = 10 Gy, b3 = 20 Gy, b4 = 30 Gy, b5 = 40 Gy, b6 = 50 Gy) were employed. All datas were statistically analyzed by using ANOVA procedure with SPSS software version 17.0. Duncan's post-hoc test was employed to verify the significant differences between the mean values ($P<0.05$).

3 Results and discussion

3.1 Color properties

Color is one of quality parameter that determines the acceptibility of food stuff [16]. The color of the arrowroot flour was observed by using a 3NH Colorimeter, which gave three color parameters including L, a, and b values. The value of L indicates the lightness level which valued from 0 to 100 [17]. The effects of different arrowroot accesions and irradiation doses on the color parameters of arrow root flour were summarized in Table 1. Results showed that the L values of samples ranging from 61.84 - 80.80. Generally, arrowroot flour with a treatment of 0 Gy show a lower value than that with higher irradiation dose. Principally, irradiation doses might induce several biochemical processes that cause discoloration [18]. The lowest L value is showed by arrow root flour of the accession of Pulosari – Pandeglang with an irradiation dose of 0 Gy (a4b2) which is (61.84) and the highest L value is MN1 accession – Bogor with an irradiation dose of 0 Gy (a5b1) which is (80.80). According to Jenjob, Uthairatanakij, Jitareerat, Wongs-Aree and Aiamla-Or [19] flour with L value close to 70, indicating the flour has a good brightness. Therefore, based on the result above, it can be concluded that the arrow root flour produced from different arrow root accession and irradiation doses exhibit bright white color which is acceptable criteria for flour [19].

Table 1 exhibits the a value of arrow root flour from different arrow root ascessions and irradiation doses ranging from 1.47 - 2.47 in which the lowest a value owned by flour from the accession of Pulosari – Pandeglang with irradiation dose of 30 Gy (a1b4) which is (1.47) . Meanwhile the highest a value is showed by Cicadas - Pandeglang accession with an irradiation dose of 20 Gy (a2b3) which is (2.47). The a value of arrow root flour from irradiation dose of 20 Gy (b3) was quite high which might be due to discoloration [18] which is induced by irradiation dose as low as 10 kGy. Thus, irradiaton doses indeeed impacted on the a color parameter of arrow root flour.

Arrow root from different accessions and irradiation dose affected the b values of arrowroot flour (Table 1). It shows that the b values of arrow root flour are ranging from 9.22 - 13.64. The lowest b value of 9.22 was shown by arrow root flour from the accession tamansari – Yogyakarta with irradiation doses of 40 Gy (a4b5). Meanwhile, the highest b value of 13.64 was found from MN1 – Bogor accession with irradiation dose of 20 Gy (a5b3). According to Khoo, Prasad, Kong, Jiang and Ismail [21] the difference of b values of arrowroot flour might be influenced by the beta carotene content. Fresh arrowroot tubers contains beta carotene of 0.01 mg / 100g which is usually appears as yellow or orange on the flesh of tubers. The carotenoids content in tubers is influenced by the tuber variety [22].

Table1. Effects of different arrowroot accesions and irradiation doses on the color parameters of arrow root flour (L*, a* and b*).

L*							a*							b*						
Accesion (a)	Irradiation dose (b)						Accesion	Irradiation dose (b)						Accesion	Irradiation dose (b)					
	0 Gy	10 Gy	20 Gy	30 Gy	40 Gy	50 Gy		0 Gy	10 Gy	20 Gy	30 Gy	40 Gy	50 Gy		0 Gy	10 Gy	20 Gy	30 Gy	40 Gy	50 Gy

	(b1)	(b2)	(b3)	(b4)	(b5)	(b6)	(a)	(b1)	(b2)	(b3)	(b4)	(b5)	(b6)	(a)	(b1)	(b2)	(b3)	(b4)	(b5)	(b6)
a1	A 67,17 Ab	A 65,55 a	AB 71,66 Abc	A 67,76 Abc	B 74,20 bc	A 75,17 c	a1	A 1,76 Abc	C 2,21 c	A 2,14 bc	A 1,47 a	AB 1,81 Abc	A 1,63 Ab	a1	A 9,92 Ab	B 10,29 Ab	A 10,74 b	A 9,32 a	A 10,35 Ab	A 9,92 Ab
a2	B 78,67 a	B 78,99 a	B 76,63 a	B 78,18 a	B 79,06 a	A 79,75 a	a2	B 2,42 bc	A 2,40 bc	A 2,47 c	B 2,17 Abc	AB 1,90 Ab	AB 1,70 a	a2	A 10,41 Ab	AB 9,99 a	A 11,43 b	B 10,47 a	A 9,66 Ab	A 9,97 a
a3	B 78,03 a	B 80,74 a	B 76,28 a	B 76,78 a	B 80,48 a	A 79,20 a	a3	AB 1,92 Abc	BC 1,58 a	A 2,17 bc	B 2,32 c	A 1,73 Ab	AB 1,98 Abc	a3	A 10,18 Ab	A 9,11 a	A 11,83 c	AB 10,39 b	A 9,45 Ab	A 10,11 Ab
a4	A 69,33 b	A 61,84 a	A 67,82 Abc	B 79,65 c	A 63,06 Ab	A 78,63 c	a4	AB 2,18 Ab	BC 1,70 a	A 2,30 b	AB 1,93 Ab	AB 1,82 Ab	AB 1,80 Ab	a4	A 10,24 Ab	AB 9,59 a	A 11,32 b	AB 9,87 a	A 9,22 a	A 9,52 a
a5	B 80,80	B 79,78	B 78,33	B 77,87	B 77,12	A 79,95	a5	A 1,83	AB 2,15	A 2,34	B 2,33	B 2,32	B 2,22	a5	A 9,74	AB 10,13	B 13,64	C 12,15	B 11,58	B 11,79

	a	a	a	a	a	a		a	a	a	a	a	a		a	A b	d	c	b c	c

Description: The average value marked by different letter notations showed a noticeable difference according to further tests of Duncan at a real level of 5%. Capital letter notation is read vertically, lowercase notation is read horizontally.

3.2 Water and oil holding capacity

WHC (water holding capacity) is a measure of the ability of flour to hold water [23]. Table 2 indicates that arrow root accessions and irradiation doses affected the WHC levels of arrowroot flour. The water holding capacity of arrow root flour are ranging from 1.36 - 1.80% in which the lowest WHC value of 1.36% is shown by arrow root flour from pulosari – Pandeglang accession with an irradiation dose of 40 Gy (a1b5). Meanwhile the highest WHC value of 1.80% is exhibited by the arrow root flour from accession of MN1 – Bogor with an irradiation dose of 0 Gy (a5b1). Irradiation may alter the functional groups within the starch molecules [10]. WHC is influenced by the strong intermolecular forces between starch polymers that easily bind the hydrogen bonds of water. Moreover, Brishti, Zarei, Muhammad, Ismail-Fitry, Shukri and Saari [24] states that the WHC value is related to the number of polar amino acid groups present in protein molecules. This is reinforced by Evers [25] who stated that water absorption is influenced by polar amino acids that own polar groups such as hydroxyl, amino, carboxyl and sulphyhydryl such as serine, tyrosine, cysteine, and tryptophan.

OHC (oil holding capacity) is used to measure the ability of flour to hold the oil it absorbs. Table 2 resumed the OHC of arrow root flour from different accesions and irradiation doses. OHC varies from 0.90 - 1.18% with the lowest OHC value of 0.90% was owned by flour on cikondang – Pandeglang accession with an irradiation dose of 10 Gy (a3b2) and the highest OHC value 1.18% of the accession of Tamansari - Yogyakarta with an irradiation dose of 10 Gy (a4b2). The OHC ability is determined by the presence of fat and fiber [26]. Fats can form a hydrophobic layer on the surface of fiber tissue, while fiber has the ability to absorb oil [27]. The OHC value is also influenced by the protein structure of a material. The proteins may also contain amino acid with non-polar groups [25, 28, 29]. Arrow root flour may contain non-polar amino acids such as isoleucine, valine, leucine, alanine, methionine, proline, phenylalanine, and glycine [20]. Flour with higher non-polar amino acids content results in higher OHC values.

Table 2. Effects of different arrowroot accesions and irradiation doses on the water and oil holding capacity (WHC and OHC) of arrow root flour.

Water Holding Capacity (WHC)							Oil Holding Capacity (OHC)						
Accession (a)	Irradiation dose (b)						Accession (a)	Irradiation dose (b)					
	0 Gy (b1)	10 Gy (b2)	20 Gy (b3)	30 Gy (b4)	40 Gy (b5)	50 Gy (b6)		0 Gy (b1)	10 Gy (b2)	20 Gy (b3)	30 Gy (b4)	40 Gy (b5)	50 Gy (b6)
a1	A 1,39 a	AB 1,54 Ab	A 1,45 Ab	A 1,43 a	B 1,62 b	A 1,36 a	a1	A 1,01 a	AB 1,04 a	A 0,98 a	A 0,95 a	B 1,18 b	B 1,14 Ab

a2	BC 1,63 b	AB 1,54 Ab	A 1,47 Ab	A 1,58 Ab	A 1,43 a	ABC 1,46 Ab	a2	AB 1,09 Ab	BC 1,14 Ab	B 1,21 b	B 1,10 Ab	AB 1,06 a	AB 1,09 Ab
a3	AB 1,54 a	A 1,44 a	A 1,48 a	A 1,47 a	AB 1,46 a	BC 1,57 a	a3	A 0,96 Ab	A 0,90 a	AB 1,06 b	AB 1,05 b	A 1,01 Ab	A 1,01 Ab
a4	AB 1,48 a	A 1,45 a	AB 1,60 a	A 1,52 a	AB 1,58 a	C 1,59 a	a4	B 1,16 a	C 1,18 a	AB 1,11 a	B 1,15 a	AB 1,06 a	B 1,18 a
a5	C 1,80 c	B 1,72 bc	B 1,68 bc	A 1,48 a	AB 1,61 Ab	AB 1,40 a	a5	AB 1,03 Ab	AB 1,02 Ab	AB 1,07 Ab	AB 1,08 Ab	A 0,98 a	AB 1,13 b

Description: The average value marked by different letter notations showed a noticeable difference according to further tests of duncan at a real level of 5%. Capital letter notation is read vertically, lowercase notation is read horizontally.

3.3 Peak, final and setback viscosities

The characteristics of flour during gelatinization is an essential knowledge to be known. According to Syafutri, Pratama, Malahayati and Hamzah [30] viscosity properties of flour during gelatinization include peak viscosity, final viscosity, and viscosity changes during cooling (setback viscosity).

Peak viscosity is the maximum point of viscosity of the paste produced during the heating process. At this point the expanding starch granules begins to break then followed by a decrease in viscosity. Peak viscosity is a criterion used to determine the ability of flour to maintain starch granules due to heating process [31]. Table 3 shows the peak viscosities of arrow root flour from different accesions and irradiation doses. The peak viscosities range from 3747-5352 cP in which the lowest peak viscosity value of 3747 cP was owned by flour of tamansari accession - Yogyakarta with irradiation dose of 20 Gy (a4b3). Meanwhile, the highest peak viscosity value of 5352 cP was showed by pulosari – Pandeglang accesions with an irradiation dose of 0 Gy (a1b1). Peak viscosity values can be influenced from various factors, namely amylose levels, protein levels, fat levels, and the size of starch granules [32]. Starch content also affects the peak viscosity. Pérez and González [33] reported that cassava flour with high starch content show high viscosity. Flour with high starch content easier to absorb water. Thus, when the high starch contained flour was heated, it produced slurry with high peak viscosity.

Final viscosity is a parameter to show the ability of starch to form a thick paste or gel after undergoing a heating and cooling process, and the resistance of the paste to friction that occurs during the stirring [34]. Table 3 exhibits the effect of arrow root accessions and irradiation doses on the final viscosity value of arrowroot flour. The peak viscosity values ranged from 2165-5098 cP with the lowest value of 2165 cP was exhibited by arrow root flour from accession of Tamansari – Yogyakarta with irradiation dose of 30 Gy (a4b4). More over, the highest value of 5098 cP was obtained from cikondang accession –

Pandeglang with irradiation dose of 20 Gy (a3b3). In general final viscosity is related to the amylose content. Flour with high amylose content exhibits high viscosity [35]. More over, the final viscosity is also influenced by fat content of flour. Fat affects the swelling of starch granules during gelatinization by forming amylose-fat complex resulting in lower viscosity [26, 32].

Setback or viscosity change during cooling is a recrystallization measurement of gelatinized starch during cooling [36]. Table 3 displays the impact of arrow root accessions and irradiation doses on the setback viscosity of arrowroot flour. The setback viscosity values ranged from 699-1506 cP with the lowest setback viscosity value of 699 cP is exhibited by arrow root flour of Tamansari - Yogyakarta accession with irradiation dose of 30 Gy. Meanwhile, the highest setback viscosity value of 1506 cP was obtained from arrow root flour of MN1 – Bogor accession with irradiation dose of 20 Gy (a5b3). Setback viscosity is an increase in viscosity when the starch paste is cooled due to starch retrogradation. Retrogradation is a process of re-crystallizing starch that has undergone gelatinization, while syneresis is the release of liquid from starch gel [37]. In addition, the setback viscosity is used as a measure of pasta product to undergo syneresis. Flour with higher setback viscosity value tends to easily undergo syneresis process [34, 37].

Table 3. Effects of different arrowroot accesions and irradiation doses on peak, final and setback viscosities of arrow root flour.

Peak Viscosity							Final Viscosity							Setback Viscosity						
Accession (a)	Irradiation Dose (b)						Accession (a)	Irradiation Dose (b)						Accession (a)	Irradiation Dose (b)					
	0 Gy (b1)	10 Gy (b2)	20 Gy (b3)	30 Gy (b4)	40 Gy (b5)	50 Gy (b6)		0 Gy (b1)	10 Gy (b2)	20 Gy (b3)	30 Gy (b4)	40 Gy (b5)	50 Gy (b6)		0 Gy (b1)	10 Gy (b2)	20 Gy (b3)	30 Gy (b4)	40 Gy (b5)	50 Gy (b6)
a1	B	A	A	B	A	A	a1	A	A	A	B	A	AB	a1	A	A	A	B	A	A
	5352	4844	5317	4585	4715	4795		4405	3575	4116	3485	3577	3341		1246	1136	1171	1080	1105	1025
	a	a	a	a	a	a		b	Ab	Ab	Ab	Ab	a		a	a	a	a	a	a
a2	A	A	A	B	A	A	a2	B	A	AB	BC	A	AB	a2	A	A	AB	BC	AB	A
	4191	4934	5106	4637	4988	5008		3115	3719	4396	3633	3666	3550		979	1205	1326	1135	1148	1045
	a	Ab	b	ab	bc	b		a	Ab	b	Ab	Ab	Ab		a	Ab	b	Ab	Ab	Ab
a3	AB	A	A	B	A	A	a3	AB	A	B	CD	AB	AB	a3	A	A	B	C	AB	AB
	4610	4562	5025	5313	4710	4561		3808	3442	5098	4545	3843	3660		1212	1158	1471	1381	1226	1117
	a	a	a	a	a	a		Ab	a	c	bc	Ab	Ab		Ab	a	b	Ab	Ab	a
a4	AB	A	A	A	A	A	a4	AB	A	AB	A	A	A	a4	A	A	AB	A	AB	A

	4661	4767	5130	3747	4951	4241		3862	4358	4668	2165	3677	2976		1886	1327	1360	699	1131	903
	bc	bc	c	a	bc	b		Bcd	Cd	d	a	bc	Ab		bc	c	c	a	bc	Ab
a5	AB	A	A	B	A	A	a5	A	A	AB	D	B	B	a5	A	A	B	C	B	B
	4561	5137	5003	5017	5005	4752		3190	4021	4885	4698	4677	4105		1050	1234	1506	1389	1406	1406
	a	a	a	a	a	a		a	Ab	b	b	b	b		a	Ab	b	b	b	b

Description: The average value marked by different letter notations showed a noticeable difference according to further tests of duncan at a real level of 5%. Capital letter notation is read vertically, lowercase notation is read horizontally

4 Conclusions

Arrow root flour produced from high irradiation doses tended to have brighter color. Arrow root flour with low water holding capacity and high oild holding capacity was produced from high irradiation doses (50 Gy) indicating the presence of non-polar amino acids and fats. Treatments (arrow root accessions and irradiation dose) do not significantly affect all pasting viscosity parameters of arrow root flour.

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