International Food Research Journal 21(1): 237-245 (2014)
Journal homepage: http://www.ifrj.upm.edu.my

Enzymatic rettings of green pepper berries for white pepper production

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Article history

Received: 12 May 2013
Received in revised form: 22 August 2013
Accepted: 29 August 2013

Keywords

Pepper berries
Physical properties
Decortications
Enzyme

Abstract

This study is carried out to determine the physical properties of green pepper berries and to improve the existing retting technique in white pepper production using the *Viscozyme* and *Celluclast* as the enzymes. Effects of blanched and non-blanched pepper berries, acidic solution and non-acidic solution, and different temperature of 28, 35, 42, and 49°C are determined to obtain the optimum conditions for enzymatic retting. The physical properties of green pepper berries such as dimension (5.21 mm), weight (0.11 g per berry), true density (1319.33 kg/m^3), bulk density (596.9 kg/m^3), sphericity (0.976), angle of repose (6.87°) and flow ability with funnel flow time of 5.27 seconds were determined. The enzymatic retting in 42^{o}C can fully soften the pericarp of pepper berries from 15 days to 7 days. The enzymatic decortication has the efficiency in acidic solution (pH 4) and temperature of 42°C with non-blanched pepper berries. The enzymatic retting reached constant fracture force (20.98N) at the ninth soaking days while the non-enzymatic retting reached constant fracture force (21.89N) at the fifteenth soaking days.

Introduction

Spices are defined as the parts of the plant, in either forms of whole or ground, which used for flavouring, colouring, seasoning, preserving, and imparting aroma in foods (Douglas *et al*., 2005). One of the popular spices is black pepper (*Piper Nigrum* L.), also known as the King of spices, is the most important and most widely used spice in the world. Black pepper is in the family of Piperaceae. The family name, Piperaceae, is derived from piper, the Latin word for pepper. Most of the European names for pepper were derived from the Sanskrit, pippali, a word used for this plant at least 3,000 years ago in India (Nelson and Cannon-Eger, 2009). Black pepper originates from the Malabar coast of Southern India, and then was spread by Hindus emigration to Indonesian and Malaysia (Anon, 2001). The green colour of pepper berries converts into black colour due to the enzymatic browning by fermentation and oxidisation of phenolic compounds which appear in the pepper berries (Amala Dhas and Korikanthimath, 2003). The green pepper berries are generally being blanched in hot water (80°C) for 1 - 2 minutes in producing black pepper for a uniform black colour as well as better flavour quality and aroma (Bunchol, 2011).

Malaysia is ranked as the sixth largest pepper producer in the world after Vietnam, India, Indonesia, Brazil and China. The annual production of Malaysia in 2005 is about 20,000 tons (Wong *et al.*, 2009). Approximately 90% of the black pepper produced in Malaysia is meant for export market and ranks fifth in the world (IPC, 2006). Sarawak is the largest pepper producing state in Malaysia which encompass for 98% of total black pepper production in Malaysia. The remaining 2% is being produced by the other states like Johor in Malaysia.

The pericarp of a pepper berry contains of three sections which are the epicarp (exocarp), mesocarp and endocarp. In white pepper production, the pericarp will rubbed off manually to obtain the pepper seeds to produce white pepper. In Sarawak, the current method for producing white pepper is soaking the fresh pepper berries in the running water (normally rivers) for 12 - 14 days after harvested and threshed. This retting technique will causes the outer skin (pericarp) of the pepper berries to be soften and rotten. After the pericarp of the pepper berries are rotten, the workers will rub off the pepper berries' pericarp by hands. Then, the pepper seeds will be cleaned in water and dried under sun for 7 - 10 days to obtain the white pepper (Bunchol, 2011). It takes almost one month to process the fresh pepper berries into white pepper. This retting technique is apparently time-consuming and requiring a large labour work. The productivity of white pepper is also limited since it consumes a long period of time to produce white pepper. There are no studies or researches on enzymatic retting technique in white pepper production.

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Viscozyme is a multi-enzyme complex produced by a selected strain of the fungus *Aspergillus aculeatus* which contains carbohydrases which are the enzymes capable to convert polymer to its monomer; carbohydrates into simpler sugars. Arabanase, cellulase, beta-glucanase, hemicellulase and xylanase are some of the carbohydrases that available in *Viscozyme*. *Viscozyme* has a wide range of uses in industry such as plants extractions, cereals and vegetables processing related fields (Anon., 2011 (a)). The common applications of *Viscozyme* are used to break down the branched pectin-like substances found in plant cell walls as in plants extractions, improving the amount of starch by degrading the non-starch polysaccharides in biomaterials during the fermentation process and improving the extraction yields by reducing the viscosity of the biomaterials derived from plants. *Celluclast* is an enzyme produced by a selected strain of the fungus *Trichoderma reesei* that is capable to breaks down cellulose into glucose, cellobiose and longer glucose polymers. Practically, *Celluclast* are similar which is to break down polymers into fermentable sugars, reduce the viscosity of soluble cellulosic substrates, or increase the yield of plant origin extracts. For practical purposes, the conditions for optimum activity of *Viscozyme* and *Celluclast* having pH and temperature ranging from 3.3 - 5.5 and 25 - 55°C respectively (Anon, 2011a; Anon, 2011b).

Many research findings on engineering properties are reported for cereal, grain and legumes but data on the black pepper are not available (Murthy and Bhattacharya, 1998). Physical properties are those characteristics that can be measured and observed without changing the composition of matter. Physical properties are used to observe and describe the characteristics of the matter (Urbicain and Lozano, 1997). Physical properties of food will directly affect the quality and the handling methods of food. According to Murthy and Bhattacharya (1998) research, black pepper seeds had a spherical shape. Average moisture content of black pepper was 8.7 to 14%, crude fiber content was 8.7 to 18% and total ash was 3.6 to 5.7% (Amala Dhas and Korikanthimath, 2003). Therefore, it is the aim of the current study to determine the physical properties of the fresh pepper berries from variety 'Khucing' such as weight, volume, size, shape, density, sphericity, flowability, and angle of repose and to determine the effects of enzymatic on decorticating of fresh pepper berries at four different temperatures. This research is important in order to improve the existing retting technique in white pepper production using the enzymatic decorticating technique.

Materials and Methods

Sample preparations

Samples of the green pepper berries from variety 'Khucing' were obtained at three different small farms in Johor, south of Malaysia. These samples were mixed together in one container under ambient temperature. Due to the distance travelled from farm to laboratory, about 8 hours had been taken for the travel time. Once the green pepper berries received, they were subjected to manual sorting and selecting process. Only full mature pepper berries were selected. The spikes with mature pepper berries will nipped off by hands. For white pepper production, spikes with one or two reddish-orange berries were collected. The over-small, immature, and defective berries were rejected. The sorted green pepper berries were put in plastic bag and store in refrigerator with 10°C for overnight. Manual threshing was carried out to remove the leaves and the spikes from the green pepper berries.

The green pepper berries were then divided into two equal portions. One portion was used for measurement of the physical properties of berries while the other portion was used for experiments of enzymatic and non-enzymatic effects on the green pepper berries. From the portion of enzymatic and non-enzymatic experiments, the pepper berries were divided again into two equal portions. One portion was subjected to hot water blanching of 80°C for 1 minute (IPC, 2008) to reduce contaminants, increase drying rate, and improve colour of the pepper berries (Bunchol, 2011). While the others portion remained in the original form. The preparation of pepper berries samples is shown in Figure 1.

Size, dimension, and sphericity

The size (diameter) of the pepper berries were measured with a digital vernier calliper with 0.01 mm accuracy (Series 500, Mitutoyo, Japan). 100 samples of pepper berries were measured and recorded. Since the pepper berries have apparent spherical shape, thus the sphericity was calculated using equation stated below (Mohsenin, 1986). The dimensions of sample taken into calculation were illustrated in Figure 3.2.

$$\text{Sphericity} = \frac{(abc)^{\frac{1}{3}}}{a}$$

Weight

The weight of pepper berry was measured using a digital balance (ER-120A, AND, Japan) with accuracy of 0.0001 g. 1000 samples of pepper berries were weighted and the value obtained was divided by

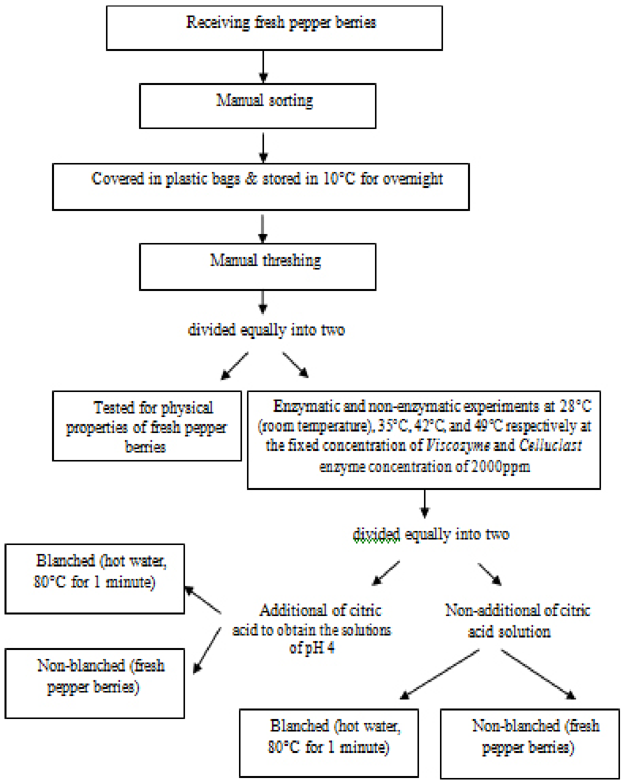

Figure 1. Flow chart of pepper berries samples preparation

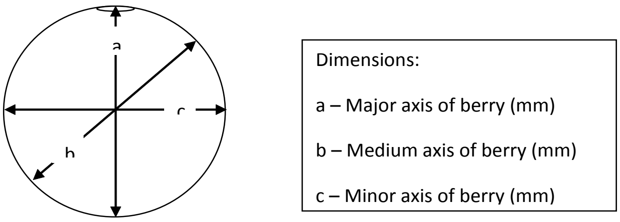

Figure 2. Dimensions of pepper berry

1000 to get the average pepper berry weight. Three replications were done.

Volume

The volume of pepper berries was estimated by water displacement method (Ravindran and Kallupurackal, 2001). 1000 samples of pepper berries were filled into a 1000 ml beaker with 500 ml water inside. Water level that displaced was recorded and the volume of 1000 samples was calculated. The value obtained for 1000 samples was divided with 1000 to obtain average volume of one pepper berry. Three replications were done.

Density

The volume and weight of pepper berry obtained before were used to calculate the true density of pepper density using the equation stated below (Karababa, 2006). The bulk density was determined by filling the samples into a 1000 ml beaker until it is full. The weight of the samples that filled into the beaker was weighted. The bulk density of the pepper berries can be calculated using equation below (Karababa, 2006). Three replications were done.

$$\text{True density} = \frac{\text{weight per berry (kg)}}{\text{Volume per berry (m}^3\text{)}}$$

$$\text{Bulk density} = \frac{\text{weight of berries in 1000ml bea ker (kg)}}{\text{Volume of 1000ml bea ker (m}^3\text{)}}$$

Colour

Colour is one of the characteristic of food which can determine the food maturity especially in fruits and vegetables. It also helps in electronic sorting and grading in food industry (Mohsenin, 1986). Color measurement of watermelon flesh was done in terms of the Commission Internationale de L'Eclairage (CIE) 'Lab' color space coordinates, where *L* represents the degree of lightness (the light to dark spectrum), *a* represents the green to red spectrum, and *b* represents the blue to yellow spectrum (Ranganna, 1986). Colour of the pepper berries were observed and measured using a colour meter (CR-10, Konica Minolta, Japan). The values of L^*, a^* and b^* obtained were used to determine the chroma and hue angle by using equation below (Mohsenin, 1986). The colour measurements of pepper berries were taken before the blanching process (fresh pepper berries), after blanching process (blanched pepper berries) and after manual rubbing (decorticated pepper berries). Ten replications were done.

$$\text{Chroma, } c^* = [(a^*)\ 2 + (b^*)^2]^{½}$$

$$\text{Hue angle, } h^* = \tan^{-1}(b^*/a^*)$$

Angle of repose

For pepper berries in bulk, the angle of repose was determined by the fixed funnel method which commonly used for testing bulk solids. The samples of pepper berries were mopped to make sure the samples were in dry condition. The conical funnel was fixed by a wooden plate called bridge. The conical funnel has a dimension of 21 cm (top) × 30 cm (height) × 2.5 cm (bottom opening). The samples were poured through the funnel to form a heap or cone. The tip of the funnel was held close to the growing cone and slowly raised as the pile grows. The pouring was stopped when the pile reaches a predetermined height. The height of the cone was measured and the angle of repose was calculated using the stated equation (Karababa, 2006). The test was repeated for three times.

$$\text{Angle of repose}, \theta = \tan^{-1}\left(\frac{2h}{D}\right)$$

Flowability

The gravitational flow of powder is equivalent to solid failure in shear. The measurement method of flowability is straightforward. This principle was adopted for measuring the flowability of pepper berries. The time (in seconds) for 1 kg pepper berries to flow through a conical plastic funnel (diameter of 150 mm top and 30 mm bottom with height of 200 mm) under gravity was reported as funnel flow time. An increase in funnel flow time indicates a decrease in flowability (Mohsenin, 1986). The test was repeated for three times.

Enzymatic and non-enzymatic experiment

According to Figure 1, there are two methods of experiments. One of the experiments is the enzymatic experiment while another one is the non-enzymatic experiment. One portions of pepper berries was blanched in hot water of 80°C for 1 minute while the other portion remained in the original form. The blanching in hot water helps in reducing contaminants, increasing the drying rate, and improving colour of the pepper berries (Bunchol, 2011). The non-enzymatic experiment was carried out to demonstrate the existing retting technique of white pepper production in Sarawak as well as to determine the optimum conditions for retting technique. The purpose of enzymatic experiment was to compare and improve the efficiency of existing retting technique. The enzymatic experiments with enzymes added to compare the existing retting technique. The enzymes that used in these experiments are *Viscozyme* and *Celluclast* (brand Novozymes from Denmark). These enzymes were provided by Malaysia Pepper Board (MPB). Both enzymes were added into the soaking water for soften the outer skin (pericarp) of pepper berries.

Both methods of experiments required the samples to be placed in the water bath in temperature of 28°C (room temperature), 35°C, 42°C, and 49°C. Previous study shows that *Viscozyme* and *Celluclast* have the optimum reactions in a temperature range of 25°C to 50°C. The samples were taken fracture force testing using the Stable Micro System Texture Analyzer (TA.XTPlus, Surrey, United Kingdom) with the P/20 cylinder. Fracture force being used to measure fractured or disintegrated with forces application. The 20 mm diameter probe was used due to its flat and wider surface for measuring the pepper berries. The probe speed was set to be 25 mm per minute with a load cell of 0.5 kN maximum capacity and the sample were compressed to half of its original diameter. Ten samples were tested.

The experiments were prepared for enzymatic experiments. Sixteen beakers (250 ml) were prepared. Eight beakers were filled with 100 g of blanched (80°C hot water for 1 minute) pepper berries each and other eight beakers were filled with 100 g non-blanched pepper berries each. Each beaker was filled with 100 ml of distilled water. 0.1 ml of *Viscozyme* and 0.1 ml of *Celluclast* (brand Novozymes from Denmark) were added into each beaker to obtain an enzyme concentration of 2000 ppm. Four beakers with blanched pepper berries and four beakers with non-blanched pepper berries were added with 0.5 ml of citric acid to obtain the solutions of pH 4. It had been reported that *Viscozyme* and *Celluclast* have the optimum activities in acidic condition, ranged from pH 3.3 to pH 5.5 (Anon, 2011a; Anon, 2011b).

The experiments were prepared for non-enzymatic experiments. Eight beakers (250 ml) were prepared. Four beakers were filled with 100 g of blanched (80°C hot water for 1 minute) pepper berries each and other four beakers were filled with 100 g non-blanched pepper berries each. Each beaker was filled with 100 ml of distilled water. The soaking water in every beaker was drained out and replaced with new 100 ml distilled water. Amala Dhas and Korikanthimath (2003) reported that the soaking water for pepper berries must be changed everyday if a running stream (river) is not available.

After the samples were prepared, all the beakers were placed in the shaker water bath (BS21, Lab Companion, Korea) with temperature of 28°C (room temperature), 35°C, 42°C, and 49°C. For both enzymatic and non-enzymatic experiments, the pepper samples were tested for fracture force everyday with texture analyzer. Both experiments ended when the fracture forces of pepper samples became constant.

Results and Discussions

Size, dimension and sphericity

Size and dimension of food are very important in screening, grading, and evaluating the quality of the food (Mohsenin, 1986). The size and dimension of green pepper berries are shown in Table 1. According to the table, the average major axis (a), medium axis (b), and minor axis (c) of the green pepper berries are 5.33, 5.20, and 5.09 mm respectively. The green pepper berries have an average diameter of 5.21

Table 1. Dimension of green pepper berries

Properties	Average	Standard deviation
Major axis, a (mm)	5.33	0.729
Medium axis, b (mm)	5.20	0.736
Minor axis, c (mm)	5.09	0.747
Average diameter (mm)	5.21	0.732
Sphericity	0.976	0.013

Table 2. Average composition of pepper berry

Physical Properties	Composition
Weight (g)	0.11 ± 0.04
Volume (m^3)	$7.6\times10^{-5} \pm 1\times10^{-6}$
Bulk density (kg/m^3)	596.9
True density (kg/m^3)	1319.33
Angle of repose (°)	6.87 ± 0.275

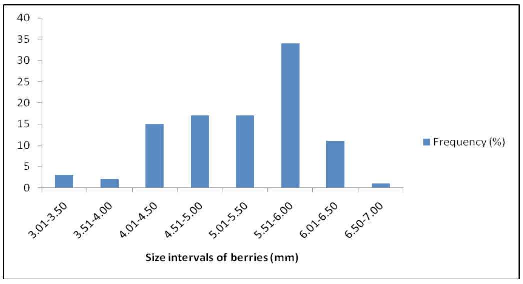

Figure 3. Size distribution of the green pepper berries from variety 'Khucing'

mm. It was found that the average diameter of green pepper berries have a higher value compared to a previous work on dried black pepper seeds (Murthy and Bhattacharya, 1998) which have a mean size of 5.12 mm.

The frequency size distribution of the green pepper berries at an interval of 0.5 mm is shown in the Figure 3. The green pepper berries have a majority distribution (34%) in interval of 5.51 to 6.00 mm. The least distribution of green pepper berries is in interval of 6.51 to 7.00 mm which only encompass for 1%. According to Murthy and Bhattacharya (1998) research, the dried black pepper seeds have a majority distribution in interval of 5.20 to 5.39 mm. Thus, the green pepper berries in Malaysia have a generally larger size (5.21 mm) and major size distribution (34% in between 5.51 and 6.00 mm) compared to the dried black pepper seeds.

Sphericity can be defined as the shape character of the solid relative to that of a sphere of the same volume. A higher value of sphericity indicates the solid are more to perfect sphere shape (Mohsenin, 1986). The perfect sphere has a sphericity value of 1. The sphericity of the green pepper berries is shown in Table 1. The sphericity of green pepper berries has an average value of 0.976 with standard deviation of 0.013 which can be considered very close to sphere shape.

Weight

Weight plays important role in determination of density, texture and quality of food. The average

Table 3. Colour values of green, blanched and decorticated pepper berries at Soaking day 1 and Soaking day 15 respectively

Properties	Average value of 10 samples					
	Soaking Day 1				Soaking Day 15	
	Before blanching		After blanching		After blanching	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
a*	-36.69	2.421	8.75	1.845	0.74	0.156
b*	40.77	3.142	10.1	1.175	6.82	0.41
L* - luminosity	42.05	1.919	25.75	1.144	89.48	1.726
c* - chroma	54.88	3.334	13.4	1.194	6.86	0.408
h* - hue angle	-47.89	2.135	49.1	4.841	83.77	1.336

weight of 1000 pepper berries is 109.87 g as shown in Table 2. The weight of one pepper berry is 0.11 g.

Volume

Volume of food is essential for determination of bulk density, transportation design, and storage design. Average volume of 1000 pepper berries is 7.6×10^{-5} m^3 with standard deviation of 1×10^{-6} as shown in Table 2. The volume of one pepper berry is 7.6×10^{-8} m^3. This value will be further used to obtain the true density and bulk density of the green pepper berries.

Density

From the experiment result, average weight of pepper berries in 1000 ml (1.0×10^{-3} m^3) beaker is 0.5969 kg. Hence, the bulk density that obtained after calculation is 596.9 kg/m^3 as shown in Table 2. It shows that bulk density green pepper berries in this study are generally higher than previous study (Jayashree *et al*., 2009). The bulk density of dried black pepper is ranged from 450 kg/m^3 to 570 kg/m^3. This may due to the different varieties of black pepper and less weight in dried black pepper seeds compared to fresh green pepper berries. The true density of green pepper berries obtained is 1319.33 kg/m^3.

Colour

Table 3 shows the colour values of fresh green pepper berries, blanched pepper berries, and decorticated pepper berries, respectively. L^* value indicates the lightness of the pepper berries; a^* value indicates the red/green colour of the pepper berries while b^* value indicates the yellow/blue colour of the pepper berries. According to Table 3 the green pepper berries shows a green colour with an average value of 42.05 (L^*), -36.69 (a^*), and 40.77 (b^*). The green pepper berries have colour ranging from mint green (42.00-L^*, - 41.00-a^* & 35.00-b^*) to turquoise green (40.00-L^*, - 36.75-a^* & 45.00-b^*) when referring to

Table 4. Average fracture forces of enzymatic experiment on soaking day 2

Enzymatic experiment				
	Fracture force (N)			
Temperature, °C	28	35	42	49
Blanched, acidic	71.55	69.76	68.45	69.53
Blanched, non-acidic	72.29	71.88	69.63	70.57
Tolerance, %	1.024	2.949	1.695	1.474
Non-blanched, acidic	68.33	67.95	65.37	68.13
Non-blanched, non-acidic	70.04	68.78	67.01	68.95
Tolerance, %	2.441	1.207	2.447	1.189

$L^*a^*b^*$ colour space (CIELAB). The green colour of pepper berries is due to the chlorophyll pigments in the berries. The variations of colours are caused by the different maturity period of each fresh pepper berry on a spike. The blanched pepper berries show a colour of mahogany brown with an average value of 25.75 (L^*), 10.10 (a^*), and 8.75 (b^*). The blanched pepper berries show colour which ranging from chocolate brown (22.00-L^*, 8.55-a^* & 7.5-b^*) to chestnut brown (27.00-L^*, 12.50-a^* & 11.00-b^*) when referring to CIELAB. The green pepper berries are generally being blanched in hot water (80°C) for 1 - 2 minutes in producing black pepper for a uniform black colour as well as better flavour quality and aroma (Bunchol, 2011). The green colour of pepper berries converts into black colour due to the enzymatic browning by fermentation and oxidisation of phenolic compounds which appear in the pepper berries (Amala Dhas and Korikanthimath, 2003). The decorticated pepper berries have a colour of creamy white with an average value of 89.48 (L^*), 0.74 (a^*) and 6.82 (b^*) when referring to CIELAB. The creamy white colour represents the colour of the pepper seeds due to the outer skin (pericarp) have been removed.

Angle of repose

The angle of repose of green pepper berries that obtained is 6.87° with a standard deviation of 0.275. The angle repose of 6.87° indicates an extremely low height (0.0207 m) of pile formed. However, the width of the pile formed is quite large with an average diameter of 0.343 m. The angle of repose reported in previous study by Murthy and Bhattacharya (1998) is ranged between 35.4° and 48.2°. This is due to the dried black pepper seeds in their study have a generally lower sphericity, which indicates that the dried black pepper seeds have a less smooth surface compared to the green pepper berries. The surface of dried black pepper berries contributes to greater friction between the seeds and thus they have a higher angle of repose.

Flowability

Flowability is the ease at which a material flows through a chute or hopper. The flowability describes

Table 5. Average fracture forces of non-enzymatic experiment on soaking day 2

Non-enzymatic experiment				
	Fracture force (N)			
Temperature, °C	28	35	42	49
Blanched	75.58	74.02	72.68	74.21
Non-blanched	74.33	73.27	71.94	73.12
Tolerance, %	1.654	1.013	1.018	1.469

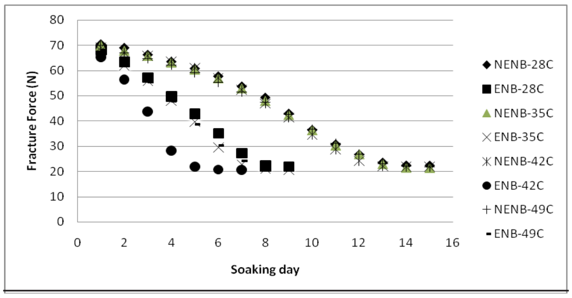

Figure 4. Comparison between enzymatic (ENB) and non-enzymatic (NENB) experiments at 28°C, 35°C, 42°C and 49°C

the shape, sphericity, surface moisture, cohesiveness characteristics of the materials. The result show that the average funnel flow time is 5.27 seconds with a standard deviation of 0.42. In previous study of Murthy and Bhattacharya (1998), the funnel flow time for dried black pepper seeds is ranged between 5.2 to 7.7 seconds. The flowability of green pepper berries is apparently better than the dried black pepper seeds since it has a shorter funnel flow time. This might due to the rough surface of the dried black pepper seeds which creates greater friction between the seeds and inhibits the funnel flow.

Fracture force

From Table 4, the non-blanched pepper berries show a lower fracture force compared to the blanched pepper berries. Taking temperature of 42°C and acidic condition, the fracture force for blanched pepper berries is 68.45 N while the fracture force for non-blanched pepper berries is only 65.37 N. The acidic condition (pH 4) for enzymatic solution also exhibits a lower fracture force compare to non-acidic enzymatic solution. Hence, the non-blanched pepper berries and acidic enzymatic solution (pH 4) have the lowest fracture force in all four different temperatures. In soaking day 2, the fracture forces of non-blanched pepper berries with acidic enzymatic solution are 68.33, 67.95, 65.37 and 68.18 N for temperature of 28, 35, 42, and 49°C respectively. This is due to enzymes (*Viscozymes* and *Celluclast*) have the optimise activity in acidic environment (Anon, 2011a; Anon, 2011b).

The average fracture forces of non-enzymatic experiment on soaking day 2 are illustrated in Table 5. The non-blanched pepper berries also shown trend of lower fracture forces compared to blanched pepper berries. Taking temperature of 42°C, the fracture force of non-blanched pepper berries is 71.94 N while the fracture force of blanched pepper berries is 72.68 N. The non-blanched pepper berries shown the lowest fracture forces which are 74.33, 73.27, 71.94, and 73.12 N for temperature of 28, 35, 42, and 49°C respectively. The tolerances in Fracture force as in Table 4 of both pairs; blanched or non-blanched in both acidic or non acidic conditions were in the range of 1.024 - 2.949%. Similarly, Table 5 showed that the tolerance for both blanched and non-blanched were in the range of 1.013 - 1.654%. Table 4 and 5 both showing that the non-blanched pepper berries have a lower fracture force compared to the blanched pepper berries.

By comparing Table 4 and 5, it is found that the enzymatic experiment has a lower fracture force in all conditions compared to non-enzymatic experiment. The enzymatic experiment has the lowest fracture forces in non-blanched pepper berries with acidic solution; the fracture forces in such conditions are 68.33, 67.95, 65.37, and 68.18 N for temperature of 28, 35, 42, and 49°C respectively. The non-enzymatic experiment has the lowest fracture forces in non-blanched pepper berries; the fracture force in such condition is 74.33, 73.27, 71.94, and 73.12 N for temperature of 28, 35, 42, and 49°C respectively. Conclusion from the both experiments has the best result (lowest fracture force) with non-blanched pepper berries and acidic enzymatic solution.

The deformation and fracture characteristics of pepper berries in enzymatic experiment with non-blanched pepper berries and acidic enzymatic solution, and non-enzymatic experiment with non-blanched pepper berries during 15 soaking storage days are both described in Figures 4, 5, 6 and 7 for temperature of 28, 35, 42, and 49°C respectively. The result shows that the initial fracture forces for all pepper berries in both enzymatic and non-enzymatic experiments are approximately 70 N. However, the enzymatic experiment does show that it has a lower initial fracture force compared to non-enzymatic experiment. It can be observed that the fracture forces for two experiments are significant decreasing ($p < 0.005$) as the soaking days increase in all four temperatures. The fracture force will reach a nearly constant value indicating that the outer skins (pericarp) of the pepper berries are soften enough and ready to be rubbed away.

Figure 4 shows that the comparison between enzymatic (ENB) and non-enzymatic (NENB) experiments in temperature of 28°C, 35°C, 42°C and 49°C. The result at 28°C shows that the enzymatic experiment has the lower initial fracture force compared to non-enzymatic experiment. This is due to the enzymatic reactions start to react on the pericarp of the pepper berries and cause the pericarp become softer than those in non-enzymatic experiment. The fracture force exhibited significant decrease ($p < 0.05$) during soaking day for both samples. The enzymatic experiment reached constant fracture force at the ninth soaking days while the non-enzymatic experiment reached constant fracture force at the fifteenth soaking days. This indicating that the outer skins pepper berries with enzymatic soaking can be rubbed earlier than non-enzymatic soaking.

The enzymatic experiment at 35°C has lower initial fracture force compared to non-enzymatic experiment. The fracture force exhibited significant decrease ($p < 0.05$) during soaking day. The enzymatic experiment reached constant fracture force at the ninth soaking days while the non-enzymatic experiment reached constant fracture force at the fifteenth soaking days. By comparing experiments at 28°C and 35°C, it can be found that the overall fracture forces in temperature of 35°C are slightly lower than those in temperature of 28°C. This may due to the enzymes (*Viscozymes* and *Celluclast*) are more active in higher temperature (Anon, 2011a; Anon, 2011b).

Result at temperature of 42°C indicates that the enzymatic experiment has lower initial fracture force compared to non-enzymatic experiment. The fracture force exhibited significant decrease ($p < 0.05$) during soaking day for both samples at 42°C. The enzymatic experiment reached constant fracture force at the seventh soaking days while the non-enzymatic experiment reached constant fracture force at the fifteenth soaking days. By comparing experiments at 42°C with 28°C and 35°C, it can be found that the enzymatic experiment required shorter time (7 days) to reach constant fracture force in temperature of 42°C compared to temperature of 28°C and 35°C which required 9 days. This may due to the enzymes are inactive in lower temperature (28°Cand 35°C) (Anon, 2011a; Anon, 2011b).

Figure 4 shows the comparison between enzymatic and non-enzymatic experiments in temperature of 49°C. Results indicate that the enzymatic experiment has lower initial fracture force compared to non-enzymatic experiment. The fracture force for both samples exhibited significant decrease ($p < 0.05$) during soaking. The enzymatic experiment reached constant fracture force at the ninth soaking days while the non-enzymatic experiment reached constant fracture force at the fifteenth soaking days at the fracture force approximately 20 N. The result also found that the enzymatic experiment required the same time (9 days) as the temperature of 28°C and 35°C to reach constant fracture force. Compared to temperature of 42°C, the enzymatic experiment in 49°C required more days (9 days) to reach the constant fracture force. This may due to the denatured of enzymes in over-high temperature (49°C) (Anon, 2011a; Anon, 2011b).

Generally, the enzymatic experiments have steeper curves compared to the non-enzymatic experiment. In four temperatures of 28, 35, 42, and 49°C, the enzymatic experiment required a shorter time which is about 7 to 9 days to reach the constant fracture force (soften the outer skin or pericarp) compared to the non-enzymatic experiment which required 15 days. Among the temperature 28, 35, 42, and 49°C, the enzymatic experiment in 42°C required the shortest time which is 7 days to fully soften the pericarp of pepper berries. When both experiments reaching the constant fracture forces, it can be observed that the enzymatic experiments have a slightly lower fracture forces compared to non-enzymatic experiments. This is due to the enzymes (*Viscozymes* and *Celluclast*) break down the cell wall and cellulose of the pepper berries (Anon, 2011a; Anon, 2011b). Thus the absorption rates of water into the pericarp of the pepper berries increase and shorten the time for pericarp softening.

Conclusion

In this study, the physical properties of green pepper berries provide useful information for developing new methods for green pepper berries retting in future. The enzymatic decortications improved the traditional retting technique with the addition of enzymes (*Viscozymes* and *Celluclast*) for softening the pericarp of pepper berries and able to shorten the retting time. The non-blanched pepper berries can exhibit a softer pericarp in both enzymatic decortications and traditional retting technique. The enzymatic decortication has the highest efficiency in acidic solution (pH 4) and temperature of 42°C with non-blanched pepper berries. From the result, enzymatic retting reached constant fracture force (20.98 N) at the ninth soaking days while the non-enzymatic retting reached constant fracture force (21.89 N) at the fifteenth soaking days.

Acknowledgements

Authors gratefully acknowledge the funding obtained from YAYASAN PAK RASHID Universiti Putra Malaysia and Research University Grants. Also thanks to the Malaysia Pepper Board (MPB) for providing the samples.

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