Investigation Of Processing Conditions For Dietary Fiber Production From Cashew Apple (Anacardium Occidentale L.) Residue

Tran Nhat Nam, Nguyen Phuoc Minh, Dong Thi Anh Dao

Abstract: Cashew is one of the most important plantation crops and widely grown in tropical areas as India, Brazil, Nigeria and Vietnam. Cashew apple (Anacardium occidentale L.) is not a true fruit, but swollen peduncle to which the nut is attached. Unlike cashew nut kernel, which has an indisputably exclusive fine taste and a commercial attractiveness of its own, cashew “apple,” despite its high nutritive values (high content of vitamin C and minerals, i.e., Ca, P, Fe) and economic potential, is virtually an unknown product in the consumer market. The edible cashew apple is the thick receptacle or “false fruit” to which the cashew nut or true fruit is attached. Cashew apple is considered as a waste in cashew nut processing industry. Various value added products such as juice, fenny, wine, dried cashew apple, syrup and jam can be prepared from cashew. Not many researches mentioned to cashew apple dietary fiber. So the aim of this research will investigate a new approach utilizing cashew apple residue to produce dietary fiber. By hydrolization, soluble fiber is pectin by enzym pectinase, carbohydrate by with following conditions ratio of cashew apple residue: water (1:6); pH 4.5; temperature for hydrolization 400C; enzyme concentration 0.3% (v/w), dietary fiber 87%.

Keywords: Cashew apple residue, value added product, approach, dietary fiber

1. INTRODUCTION

1.1 Cashew apple

The cashew, *Anacardium occidentale*, is a tree in the family Anacardiaceae which produces a seed that is harvested as the cashew nut. Classification of cashew:

Kingdom: *Plantae*
Order: *Sapindales*
Family: *Anacardiaceae*
Genus: *Anacardium*
Species: *A. Occidentale*

Cashew tree (*Anacardium Occidentale L)* is a perennial plant originated from Northeastern Brazil, but now widely grown in Vietnam, India, Nigeria, Tanzania, Indonesia, Guinea-Bissau, Cote D'Ivoire, Mozambique và Benin. They have other names such as Cashew (England), Caju or Cajueiro (Portugue), Anacardier (France), Merey (Venezuela), Maranon (Span)… and Dao Lon Hot (Vietnam)

Figure1. Weight of cashew apple: 8 – 10 times that of nut

1.2 Composition of cashew apple

Cashew apple fruit includes two parts: true and false fruit. The true fruit is surrounded by shell and nut, false fruit is developed from pedicel. False fruit contains 90% whole fruit weight. The pulp of the cashew apple is very juicy with 85-90% water, 7-13% carbohydrate, 0.7– 0.9% protein, 0.2% mineral, 0.1 lipid, vitamin C at high content (261.5 mg per edible part), five or six fold compared to orange, eight fold compared to mandarin orange, other vitamins (B1, B2, etc), and minerals (Ca, P, Fe, etc). However, pulp of the cashew apple is usually discarded during harvest, which is wasteful and harmful to environment [2, 13].

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Table 1. Composition in 100 g cashew apple pulp [2, 13]

Composition	Content	Unit
Moisture	84.4 – 88.7	%
Protein	0.101 – 0.162	G
Fat	0.05 – 0.5	G
Carbohydrate	9.08 – 9.75	G
Total fiber	0.4 – 1.0	G
Ash	0.19 – 0.34	G
Cancium	0.9 – 5.4	Mg
Phosphorus	6.1 – 21.4	Mg
Iron	0.19 – 0.71	Mg
Thiamine	0.023 – 0.03	Mg
Riboflavin	0.13 – 0.4	Mg
Niacin	0.13 – 0.539	Mg
VitaminC	147 – 372	Mg

1.3 Several studies about value added products from cashew apple

The cashew apple is used mostly for the production of juice. Its residue is composed of the skin and the husk and is frequently used for animal feed or even wasted. The residue has a dark yellow color, a fibrous aspect, and a typical adstringent aroma due to the presence of tannins which could be a limiting factor for the acceptability of the cashew apple and the juice, especially in foreign countries. More recently, many studies have been conducted to develop new cashew products and to make a better use of this source [10]. Shuklajasha Mohanty et al (2006) prepared an undistilled alcoholic beverage (wine) by fermenting cashew apple juice with wine yeast, *Saccharomyces cerevisiae* var. *bayanus* [12]. T. Neelakandan and G. Usharani (2009) optimize and produce bioethanol from cashew apple juice using immobilized yeast cells by *Saccharomyces cerevisiae* [14]. P. Suganya and R. Dharshini (2011) summarized various added products from cashew apple such as juice, fenny, wine, dried cashew apple, syrup and jam [10]. Arindam Kuila et al (2011) carried out a process optimization for aqueous extraction of reducing sugar from cashew apple bagasse: A potential, low cost substrate [3]. Nguyen Thi Thuy Giang et al (2013) used fruit juice from cashew apple as a substrate for the growth of Lactobacillus acidophilus to create a new probiotic beverage for human health and decrease environmental impurity from ripe cashew apples [9]. Regarding to cashew apple fiber from its residue, there are not many researches mentioned [1, 4, 5, 6, 11]. Maria do Socorro M. Rufino et al. (2010) evaluated acerola and cashew apple as sources of antioxidants, dietary fibre and phenolic compounds [8]. Lívia Xerez Pinho et al (2011) studied to produce hamburgers with partial substitution of the meat with cashew apple residue powder. The production of hamburgers with a partial substitution of cow meat with the cashew apple residue could be a feasible option since it resulted in product with high nutritional quality that is rich or have high dietary fiber content and is low in fat [7]. The scope of iour research is to focus on optimal processing conditions to get the highest amount of cashew apple dietary fiber, a value added products from cashew nut processing industry.

2 MATERIAL AND METHODS

2.1 Raw material

Cashew apple fruits are collected in Dong Nai province; utilize the pulp of cashew apple residue as material for investigation. Enzyme reagents Pectinex ultra SP_L and Termamyl are provided from Modernist Pantry and Novozymes Co. Ltd

2.2 Flow chart for processing cashew apple dietary fiber

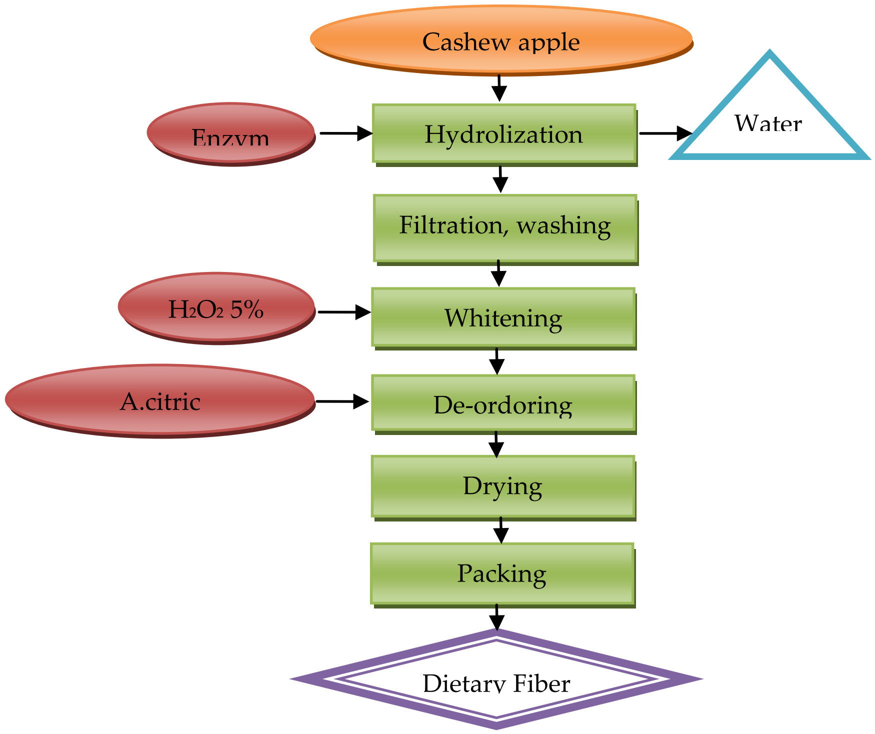


Figure 2. Flow chart for processing cashew apple fiber

2.3 Effect of residue: water to hydrolization by enzyme Pectinex ultra SP_L

2.3.1 Experimental parameter: Ratio of residue: water (w/v) (1:4, 1:5, 1:6, 1:7, 1:8)

2.3.2 Fixed parameter: Enzyme concentration 0.1%, temperature 45°C, pH 5.0

2.3.3 Target parameter: Crude fiber (g), fiber recovery (%)

2.4 Effect of temperature to hydrolization by enzyme Pectinex ultra SP_L

2.4.1 Experimental parameter: Temperature 30°C, 40 °C, 45 °C, 50 °C, 55 °C

2.4.2 Fixed parameter: Enzyme concentration: 0.1%, residue:water optimized from experiment #2.3, pH 5.0

2.4.3 Target parameter: Crude fiber (g), fiber recovery (%)

2.5 Effect of enzyme concentration to hydrolization by enzyme Pectinex ultra SP_L

2.5.1 Experimental parameter: *Enzyme concentration 0.1%, 0.2%, 0.3%, 0.4%*

2.5.2 Fixed parameter: Residue:water optimized from experiment #2.3, temperature optimized from experiment #2.4, pH 5.0

2.5.3 Target parameter: Crude fiber (g), fiber recovery (%)

2.6 Effect of pH to hydrolization by enzyme Termamyl

2.6.1 Experimental parameter: *pH 5.0, 5.5, 6.0, 6.5*

2.6.2 Fixed parameter: Residue:water optimized from experiment #2.3, temperature 90°C, enzyme concentration 0.6%

2.6.3 Target parameter: Crude fiber (g), fiber recovery (%)

2.7 Effect of temperature to hydrolization by enzyme Termamyl

2.7.1 Experimental parameter: *temperature pH 80* °C, 85 °C, 90 °C, 95 °C

2.7.2 Fixed parameter: pH optimized from experiment #2.6, enzyme concentration 0.6%

2.7.3 Target parameter*:* Crude fiber (g), fiber recovery (%)

2.8 Effect of enzyme concentration to hydrolization by enzyme Termamyl

2.8.1 Experimental parameter*:* enzyme concentration 0.4%, 0.5%, 0.6%, 0.7%, 0.8%

2.8.2Fixed parameter: pH optimized from experiment #2.6, temperature optimized from experiment#2.7

2.8.3 Target parameter: Crude fiber (g), fiber recovery (%)

2.9 Effect of drying temperature to sensory quality of cashew apple dietary fiber

2.9.1 Experimental parameter: Temperature 60^{o}C, 70 ^{o}C, 80 ^{o}C, 90 ^{o}C

2.9.2 Fixed parameter: Sample weight

2.9.3 Target parameter: Moisture content, drying duration

2.10 Analytical methods

Determine moisture content: TCVN 5613 – 91
Determine total sugar: TCVN 4594 – 88
Determine pH: pH meter
Determine soluble dry matter: refractometer
Determine tannin: ISO 9648:1988
Determine vitamin C: TCVN 4715 – 89
Determine polyphenol: Folin – Ciocalteau
Determine total nitrogen: Kjeldahl (AOAC 960.52)
Determine ash: TCVN 5611 – 91
Determine crude fiber: TCVN 4329-2007
Determine microorganism: colony counting
Determine enzyme activity: Ansons
Determine lipid: Soxhlet

3. RESULTS AND DISCUSSION

3.1. Composition of cashew apple residue

Table2. Composition of cashew apple residue

Composition	Cashew apple residue
Protein (%)	0.027
Lipids (%)	0.038
Ash (%)	0.9
Moisture (%)	73±2

3.2. Hydrolization with enzyme Pectinex ultra SP_L

3.2.1 Effect of residue: water to hydrolization

Table 3. Effect of residue:water to crude fiber

Residue : water (w/v)	1:4	1:5	1:6	1:7	1:8
Crude fiber (g)	2.60^{bc}	2.58^{b}	2.42^{a}	2.40^{a}	2.64^{c}
Crude fiber recovery (%)	96.30	95.56	89.63	88.89	97.78

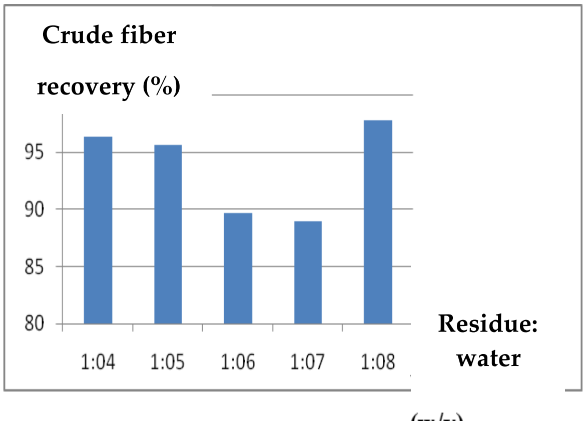


Figure 3. Effect of residue:water to crude fiber recovery (%)

Our result shows that ratio of residue:water has correlation to hydrolization of enzyme Pectinex ultra SP_L. At ratio residue:water 1:6 and 1:7 we get the minimum amount of crude fibe (2.42 and 2,37g), the smallest recovery (89.63 và 87.78%) and ther is no statistically significant difference at these ratios. This means at at these ratios enzyme will strongly activate to hydrolyze pectin. Meanwhile, at ratio residue:water 1:8 enzyme activates at the lowest so we get high fiber recovery (97.78%); that means there is a small amount of pectin hydrolyzed by enzyme Pectinex ultra SP_L. At the low ratio of residue:water, enzyme will be unevenly distributed in sample so fiber recovery will be low also. Contrary, if ratio of residue:water is too high, enzyme is diluted and affected to interaction between enzyme and substrate, subsequently hydrolization will not be effective. In this experiment, we choose ratio of residue:water 1:6 for further experiments.

3.2.2 Effect of pH to hydrolization

pH has comprehensively affected to enzyme reaction because it defines the interaction between enzyme and substrate as well as enzyme stability. Every enzyme has an optimum pH value so it's very necessary. When pH increases from 4.0 to 5.5, crude fiber decreases from 2.46 to 2.42 and crude fiber recovery also downs from 91.11% to 89.13% and at pH 4.5 crude fiber and crude fiber recovery also present at the lowest levels. This demonstrates Pectinex enzyme activity at pH 4.5 is activated to other pH values. So we choose pH 4.5 for further experiments.

Table 4. Effect of pH to crude fiber

pH	4.0	4.5	5.0	5.5
Crude fiber (g)	2.46[b]	2.23[a]	2.29[a]	2.41[b]
Crude fiber recovery (%)	91.11	82.59	84.81	89.13

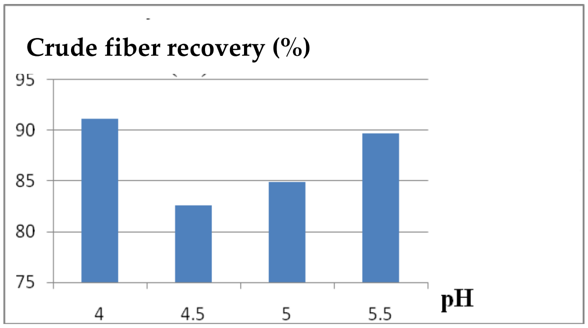


Figure 4. Effect of pH to crude fiber recovery (%)

3.2.3 Effect of temperature to hydrolization

Catalytic speed by enzyme only increases to temperature in a defined range. If it gets too high, protein will be denatured unreversibly, enzyme inactivated and biochemical reaction ceased**.** At low temperature, enzyme will also be inactivated but reversibly. So we should define optimal temperature for enzyme activation. Temperature strongly affects to hydrolization by enzyme Pectinex ultra SP_L. When it inceases from 30^{0}C to 40^{0}C, reaction will execute faster and crude fiber decrease (40^{0}C, 2.21g crude fiber and crude fiber recovery 81.85%). When temperature increases from 40^{0}C to 55^{0}C, crude fiber expands from 2.42 to 2.55 g and crude fiber recovery also goes up 81.85% to 94.44%. This phenomenon can be expressed that when temperature inceases from 30^{0}C to 40^{0}C this will enhance the interaction between enzyme and substrate as well as free movement of molecules and exchanging probability. So 40^{0}C is selected for further experiments.

Table 5. Effect of temperature to crude fiber

Temperature (^{0}C)	30	40	45	50	55
Crude fiber (g)	2.61[d]	2.21[a]	2.42[b]	2.47[b]	2.55[c]
Crude fiber recovery (%)	96.67	81.85	89.63	91.48	94.44

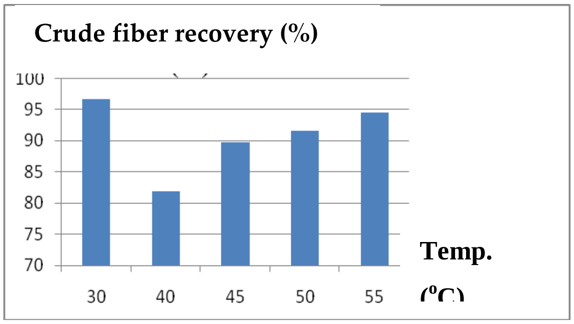


Figure 5. Effect of temperature to crude fiber recovery (%)

3.2.4 Effect of enzyme concentration to hydrolization

Transformation of substrate to product will be proceeded faster if adding more enzyme, however this will also negatively press to cost. So it's very necessary to define appropriate enzyme concentration to get the best hydrolization. If enzyme concentration extends from 0.1% to 0.4% crude fiber recovery is suppressed and crude fiber deducts from 2.21 to 2.01g; at 0.3% and 0.4% we receive the lowest crude fiber and crude fiber recovery. We select enzyme concentration 0.3% for further experiments.

Table 6. Effect of enzyme concentration to crude fiber

Enzyme concentration (%)	0.1	0.2	0.3	0.4
Crude fiber (g)	2.21[c]	2.07[b]	2.03[a]	2.01[a]
Crude fiber recovery (%)	81.85	76.67	75.19	74.44

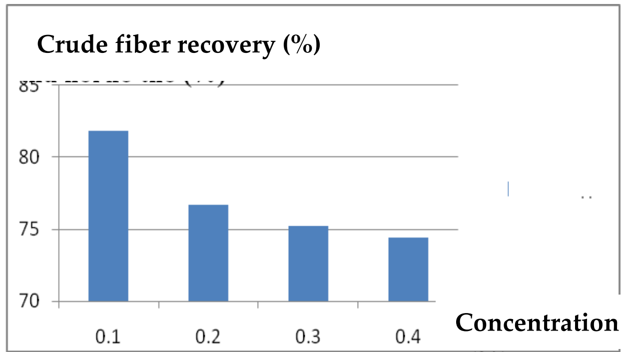


Figure 6. Effect of enzyme concentration to crude fiber recovery (%)

3.3 Hydrolization with enzyme Termamyl

3.3.1 Effect of pH to hydrolization

Table 7. Effect of pH to crude fiber

pH	5	5,5	6	6,5
Crude fiber (g)	2.53[d]	2.38[b]	2.35[a]	2.43[c]
Crude fiber recovery (%)	93.70	88.15	87.04	90.00

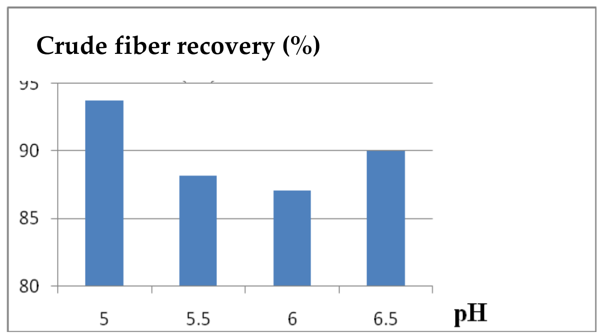


Figure 7. Effect of pH to crude fiber recovery

Crude fiber gradually decreases (93.70% to 87.04%) when pH increases from 5 to 6 and the highest crude fiber recovery at pH 6 (87.04%). This trend will steep to pH 6.5. Finally we choose pH 6 for further experiments.

3.3.3 Effect of temperature to hydrolization

Table 8. Effect of temperature to crude fiber

Temperature (^{0}C)	80	85	90	95
Crude fiber (g)	2.47[c]	2.36[b]	2.29[a]	2.30[a]
Crude fiber recovery (%)	91.48	87.40	84.81	85.18

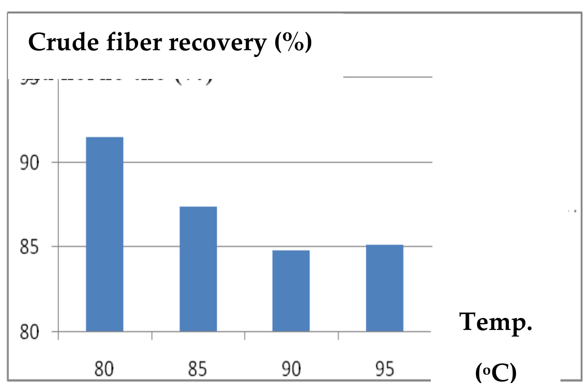


Figure 8. Effect of temp. to crude fiber recovery

Similarly to pH, each enzyme has an optimal tempearature. Our study proves when temperature increases from 80^{0}C to 90^{0}C hydrolytic speed will go up, and turn down if it's over 95^{0}C. Crude fiber and crude fiber recovery get the lowest values (2.29g and 84.81 %) at 90^{0}C. So this temperature is ideal for hydrolization and we choose it for further experiments.

3.3.4 Effect of enzyme concentration to hydrolization

Table 9. Effec of enzyme concentration to crude fiber

Enzyme (%)	0.4	0.5	0.6	0.7	0.8
Crude fiber (g)	2.48[d]	2.42[c]	2.32[a]	2.37[b]	2.38[b]
Crude fiber recovery (%)	91.85	89.63	85.93	87.78	88.15

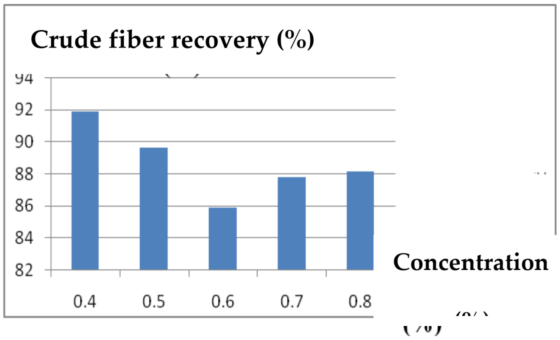


Figure 9. Effect of enzyme concentration to crude fiber recovery

3.4 Comparison the crude fiber recovery between Pectinex ultra SP_L and Termamyl.

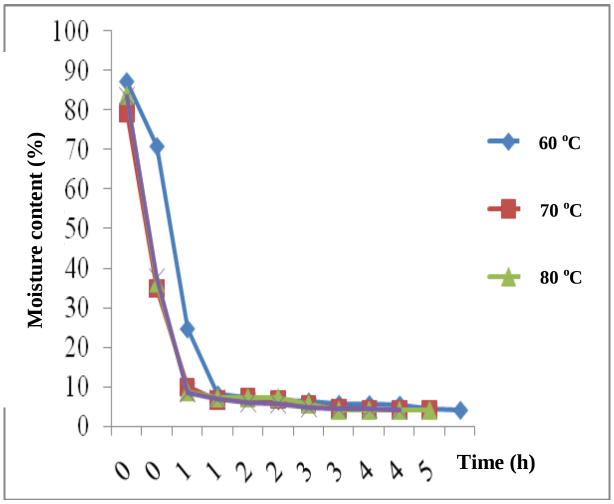
Table 10. Difference of fiber recovery between Pectinex ultra SP_L and Termamyl

Enzyme	Pectinex ultra SP_L	Termamyl
Crude fiber recovery (%)	75.19	85.93

Our result demonstrates one interesting point that the crude fiber recovery treated by Termamyl is superior to Pectinex ultra SP_L. This phenomenon can be explained as follow: Pectinex hydrolytes pectin in cashew apple residue into soluble particles then washed out, whilst Termamyl strongly hydrolytes glucid so it can remove a small dry matter in residue. So we decide to choose enzyme Pectinnex ultra SP_L to hydrolyte cashew apple residue to get dietary fiber.

3.5 Effect of drying temperature to drying duration and sensory product quality

Drying is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid. This process is often used as a final production step before selling or packaging products. Usually, in this period, it is surface moisture outside individual particles that is being removed. The drying rate during this period is dependent on the rate of heat transfer to the material being dried. Therefore, the maximum achievable drying rate is considered to be heat-transfer limited. If drying is continued, the slope of the curve, the drying rate, becomes less steep (falling rate period) and eventually tends to nearly horizontal at very long times. The product moisture content is then constant at the equilibrium moisture content, where it is in dynamic equilibrium with the dehydrating medium. In the falling-rate period, water migration from the product interior to the surface is mostly by molecular diffusion, i,e. the water flux is proportional to the moisture content gradient. This means that water moves from zones with higher moisture content to zones with lower values, a phenomenon explained by the second law of thermodynamics. If water removal is considerable, the products usually undergo shrinkage and deformation, except in a well-designed freeze-drying process. The drying rate in the falling-rate period is controlled by the rate of removal of moisture or solvent from the interior of the solid being dried and is referred to as being "mass-transfer limited". In our research, moisture content in raw fiber reduces dramatically in one first hour to below 10% when drying at 70, 80 and 90^{o}C. Meanwhile drying at 60^{o}C, moisture content will be higher 24% and need 1.5 hours to get below 10%. Duration required to get fiber moisture content below 5% (in powder) is 3-3.5 hours at 70^{o}C, 80 ^{o}C and 90 ^{o}C, while 4.5 hours to deduct fiber moisture content to 5% at 60^{o}C. In order to define the appropriate temperature, we also investigate the drying process under the sensory evaluation for cashew apple fiber product. The higher temperature, the darkness and curdle appearance to fiber powder. Reason of this darkness is owing to Maillard reaction created by protein and starch remained in cashew residue. If drying at 60^{0}C fiber will be brighter and smoother after crushing. We decide to choose 60^{0}C and 4.5h for drying cashew apple fiber.



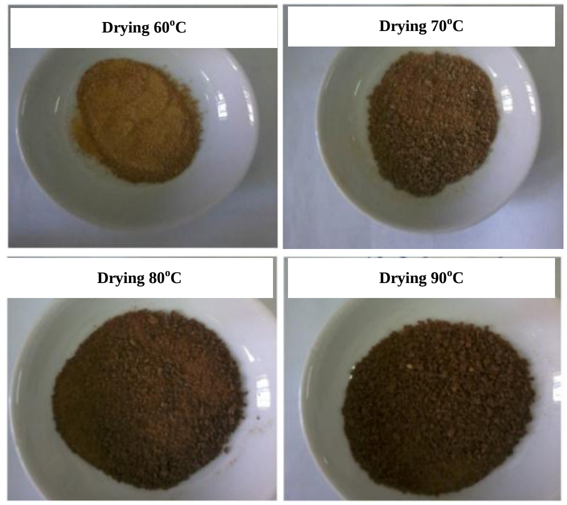


Figure 10. Effect of drying temperature and drying duration to moisture content

Figure 11. Cashew apple fiber dried at different temperatures

3.6 Chemical composition of cashew apple dietary fiber

Cashew apple fiber after drying and crushing become silky powder. We demonstrate some characteristics in its composition.

Table 11. Chemical composition of cashew apple fiber powder

No	Composition	Unit	Value
1	Moisture	%	4,237
2	Protein	%	1,1
3	Lipid	%	0,36
4	Carbohydrate	%	4,5
5	Ash	%	0,9
6	Fiber	%	87%

We see the chemical composition in cashew apple fiber having protein 1.1%; lipid 0.36%, carbohydrate 4.5%, ash 0.9% and fiber 87%. High content of dietary fiber in cashew apple powder is apparently applied for human consumption. Moisture content should be kept < 5% to ensure long-term shelf-life.

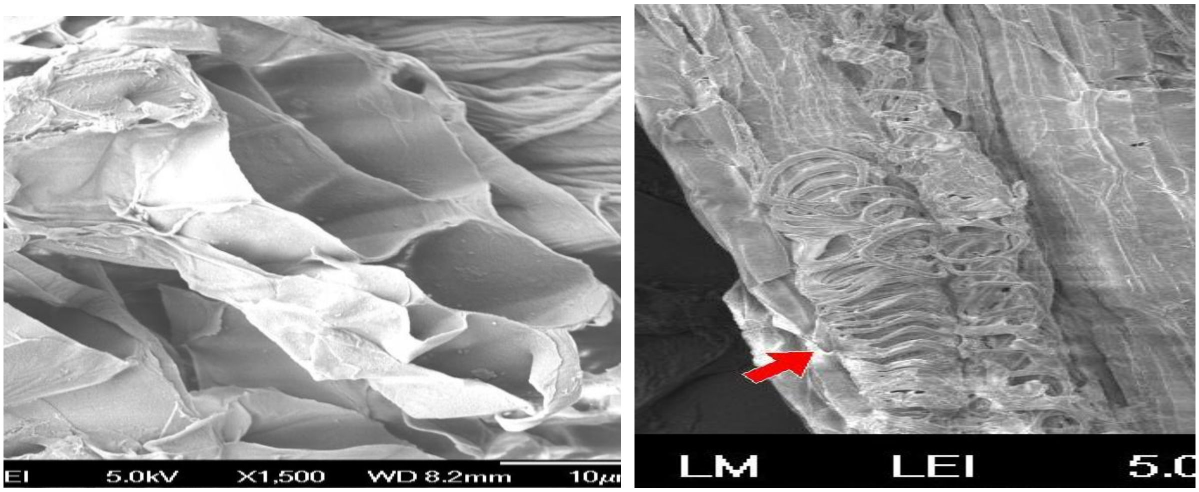


Figure 12. Microscopic structure of cashew apple fiber under SEM photograph

4. CONCLUSION

In our research, we draw our some main points for cashew apple fiber production such as enzyme Pectinex ultraSP_L; ratio of cashew apple residue: water (1:6); pH 4.5; temperature for hydrolization 40^0C; enzyme concentration 0.3% (v/w), dietary fiber 87%. This approach can be considered a very feasible trend to be commercialized in food market, functional food or naturally dietary supplements.

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