Enhancement of Pulp Sheet from OPEFB by Using Composite Latex for Packaging

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Abstract

Oil palm empty fruit bunch were normally acquired as waste product of palm oil industries. The objectives of this research are to recovery and utilization of pulp of oil palm empty fruit bunches (OPEFBs). The possibilities of OPEFB's pulp have yet been developed for commercial innovation. The molded pulp cushioning of packaging from OPEFB was improved the mechanical properties with the composite latex. It has many advantages as well as high flexibility, durability, water resistance, non-toxic and environmentally friendly. Chemical pulp of OPEFB was produced by the kraft pulping process and the optimum condition was demonstrated. The results demonstrated that the kraft pulping process with the EA 20% on dried wood basis, cooking time 120 minutes, and cooking temperature of 180°C provided the best yield and mechanical properties. The molded pulp cushioning from OPEFB's pulp could be improvement by coating with composite latex. Three formulas of composite latex coating contributed the mechanical properties have not significantly but there are differences of appearance. The third formula provided the best appearance. The elongation at break of molded pulp cushioning coated with composite latex was greater than that molded pulp cushioning has not the composite latex coating up to 150 times. The good flexibility of molded pulp cushioning with composite latex coating demonstrated its good impact resistance. Therefore, it has the potentiality to apply as a cushioning material for packaging.

Keywords: OPEFB, molded pulp, composite latex, packaging.

Introduction

Oil palm is one of the major industrial crops of the southern locale of Thailand. Palm oil production produces a lot of solid residues including shells, cellulosic fibers and oil palm empty fruit bunches (OPEFB) (Sathawong *et al.*, 2018a, Sathawong*et al.*, 2018b). The explosive expansion of oil-palm factories in Thailand has generated enormous amounts of solid waste, creating problems in replanting operations, and tremendous environmental concerns (Chavalparit *et al.*, 2006). At present, OPEFB solid wastes have turned into a major trouble of elimination in the oil palm industry. In any case, the previous research demonstrates that OPEFB fiber is made up from a complex matrix of three principle polymers which are cellulose, hemicellulose and lignin. It constituted approximately around 43.2% cellulose, 32.5% hemicellulose and 26.2% of the lignin (Boerjan *et al.*, 2003; Rosli *et al.*, 2004). The kraft process is the most commanding chemical pulping process. The expression of “sulfate” is gotten from the constitution sodium sulfate. The kraft process includes the recuperation around to constitution for chemical lost. The active cooking chemicals of kraft pulping process are sodium sulfide (Na_2S) and sodium hydroxide (NaOH) (Sridach, 2010). The kraft pulp contributed the better pulp quality in contrast to sulphite pulp. The kraft pulping process delivered an assortment of pulps utilized principally to package and high-quality papers and paperboard. It has affected to the environmental controls on outflows from industry, for example, add up eliminated solids, sulfur compound, sulfur dioxide, and wastewater contamination. Many researches have been studied and looked for a new, non-wood raw material for paper production. It has been conducted in Europe and North America (Anttila *et al.*, 2012; Karjalainen *et al.*, 2013; Le Normand *et al.* 2012). The cellulose fibers about 60% originate in developing country from non-wood materials such as bagasse (sugarcane fibers), cereal straw, bamboo, reeds, and OPEFB.

Oil palm empty fruit bunches (OPEFB) is a by-product of palm oil process in the factories. It is a hitherto unexploited source of lignocellulosic biomass. Normally, the solid wastes in palm oil factories obtained from the empty fruit branches (34%), OPEFB (11%) and palm kernel shell (8%). (Prasertsan and Prasertsan, 1996). Land dumping of these wastes creates environmental problems including the lack of suitable sites and the risk of accidental fires. An alternative to decrease the environmental problem is to develop the biomass for fibrous products such as paper (Gominho *et al.*, 2000), fiberboard (Khalil *et al*, 2017) and aerogel (Sathawong *et al.*, 2018a, Sathawong *et al.*, 2018b).

Most of this research has been measured the chemical compositions of OPEFB with the optimum conditions and produced the molded pulp cushioning from OPEFB for package. Chemical pulp of OPEFB, as a raw material of molded pulp, was produced by kraft pulping process and the OPEFB’s pulp sheet was coated by composite latex. The optimum kraft pulping condition and the proper ratio of OPEFB and composite latex coating was established.

Objectives

1) To study the OPEFB by the kraft pulping process to select the optimal conditions for producing molded pulp products.

2) To develop the production process of OPEFB by using composite latex, which is environmentally friendly biomaterial.

Experimental

Raw material and chemical analysis

Oil palm empty fruit bunches (OPEFBs) were derived from the Virgin Vegetable Oil Co., Ltd., Songkhla, Thailand. Na_2S, NaOH, H_2SO_4, and other chemicals were purchased from Merck, Germany.

Chemical composition of OPEFB was analyzed such as cellulose (Applied from Van Soest and Wine, 1967), lignin (Applied from Van Soest and Wine, 1967), ash (TAPPI T211 om-85), moisture content (TAPPI T264), pentosans (TAPPI T223 om-84), solvent extractive of wood (TAPPI T204 om-88), solubility in hot and cold water (TAPPI T207 om-88) and solubility in 1% NaOH (TAPPI T212 om-88).

Preparation of OPEFB’s and pulp sheet

Chemical pulp of OPEFB was produced by kraft pulping process and the optimum pulping condition was investigated. OPEFB and cooking liquor (a mixture of sodium hydroxide and sodium sulfide) were cooked in a digester that are capable of withstanding high pressures with sulfidity is 40%, effective alkali (EA) 15 and 20% (w/w) and the ratio of

OPEFB to white liquor is 1:8 (w/v). The cooking conditions are 90 and 120minutes at 150°C and 180°C.After cooling, the fibers were separated by a wire mesh test sieve. The screened pulp yield of kraft pulping was calculated and then the pulp sheets were made by a laboratory paper making machine at a final grammage of 140 g/m^2.

Preparation of composite latex

Composite latex was prepared by mixing SBR rubber with 50% of china clay and 50% of wood resin for 30 minutes after that added 50% of sulphur dispersion and then stirred for 30 minutes.

Preparation of composite latex

The pulp sheets, grammage of 320 g/m^{2}and dipped to the composite latex for 30, 60 and 90seconds. They were cured at room temperature (25-27^{o}C) and dried in hot air oven at 105^{o}C for 5 minutes. Physical and mechanical properties of coated and uncoated specimens were investigated. Ten specimens were used for testing of tensile strength test (TAPPI T494 om-88) burst test (TAPPI T403 om-91), ring crush test (TAPPI T818 om-92) and optical appearance.

Statistical data analysis

All mechanical properties of paper were determined at least six replicates. The mean and standard deviations were calculated and reported. Analysis of variance (ANOVA) was operated by using Duncan’s new multiple range test (DMRT) to decide the significant differences of paper properties. All significant values were expressed at 95% confidence level.

Result and Discussion

Raw material and chemical analysis

Chemical composition of OPEFB was investigated and compared to the other sources of fiber were also shown in Table 1.

Table 1:Chemical composition of OPEFB and other fibers basedon dried wood basis.

Items	OPEFB	Wheat straw (Jiménez *et al.*, 2005)	Rice straw (Jiménez et al., 1976)	Eucalyptus (Jiménez et al., 1996; Alonso, 1976)	Pine (Jiménez et al., 1996; Alonso, 1976)
Moisture	4.86	8.27	9.83	7.36	7.27
Ash	5.12	7.22	15.39	0.53	0.45
Cold water solubility	11.35	11.44	10.53	2.52	1.58
Hot water solubility	17.80	13.80	16.57	2.88	1.95
1% soda solubility	42.40	30.04	46.94	12.62	9.94
Cellulose	34.62	59.04	-	66.01	81.53
Lignin	25.10	18.94	25.23	20.60	27.54
Pentosan	12.18	20.48	22.52	21.23	13.07
Ethanol-benzene extractables	3.76	11.49	1.40	1.28	1.75

Table 1 demonstrated the chemical composition of OPEFB compared to those previously obtained for pine, eucalyptus, and various non-wood raw materials (viz. wheat straw, and rice straw) (Jiménez et al., 2006; Alonso, 1976). The moisture content of OPEFB was lower than those of the other raw materials. The ash content is lower than wheat and rice straw but higher than pine and eucalyptus. The ash contents of the nonwoodfiber are still high for industrial processing, especially given the higher ash than in wood due to the nonwoodfibers generally have higher silicon, nutrient and hemicelluloses contents than wood fibers (Hunter, 1988). Hot and cold water soluble materials of OPEFB were higher than wood fibers, (e.g. pine and eucalyptus) but similar to those of wheat straw and rice straw. Both hot and cold water for those of the other raw materials were suggesting higher contents of inorganic compounds, tannins, gums, sugars, coloring matter or starches in the sample.

Wood and nonwoodfibers were extracted with 1% sodium hydroxide solution for 1 hour. Alkali solution extracts low molecular weight carbohydrates in pulps. The solubility of OPEFB in alkali solution was similar to those of rice straw but higher than those of wood fibers. The solubility of fibers indicates an extent of cellulose degradation during pulping processes and it has been related to strength and other properties of pulps.

The solubility of OPEFB in ethanol-benzene solutions was 3.76% d.b., lower than vine shoots, but it was higher than those of rice straw, eucalyptus and pine. The solubility of fibers in ethanol-benzene solution indicates an extractable content of wood consists of certain other dichloromethane-insoluble component, such as low molecular-weight carbohydrates, salts, waxes, fats, resins, non-volatile hydrocarbons in during pulping processes. The cellulose of OPEFB was rather low comparing to other raw materials. Cellulosic fibers has many features which fulfill the requirement of papermaking for paper manufactures. Lignin of OPEFB

The pentosans content of OPEFB was 12.18%. It was lower than those of the other raw materials. The pentosans contents indicate the retention or loss of hemicelluloses during pulping processes, and since hemicelluloses contribute to the strength of paper pulps, high pentosans content is likable. Normally, pentosans content in softwood and hardwood were 6-9% and 17-25%, respectively (TAPPI, 1984).

Preparation of OPEFB’s pulp

The key performances of the optimal pulping were the pulp yield of OPEFB and quality of pulp sheets (shown in Figure 1 and Figure 2). The highest pulp yield of kraft pulping process was 22.78% (d.b.) which obtained from the kraft pulping condition of EA 20% (w/w), cooking time 120 minutes, and cooking temperature of 180°C (20/120/180). Moreover, this condition contributed the highest tensile indices are illustrated in Figure 2. Tensile indices of the pulp sheets were the range of 4.88-7.52 Nm/g.Tensile index (TI) is a measure of the material resistance under fracture stress. It depends on the strength, length and surface area of the fibers and the strength of bonding between them (Hirn et al., 2015 and Araújo et al., 2013).The results demonstrated that a maximum tensile index (TI) of pulp sheets obtained from the kraft pulping condition of EA 20% (w/w), cooking time 120 minutes, and cooking temperature of 180°C (20/120/180)was 7.52 Nm/g.

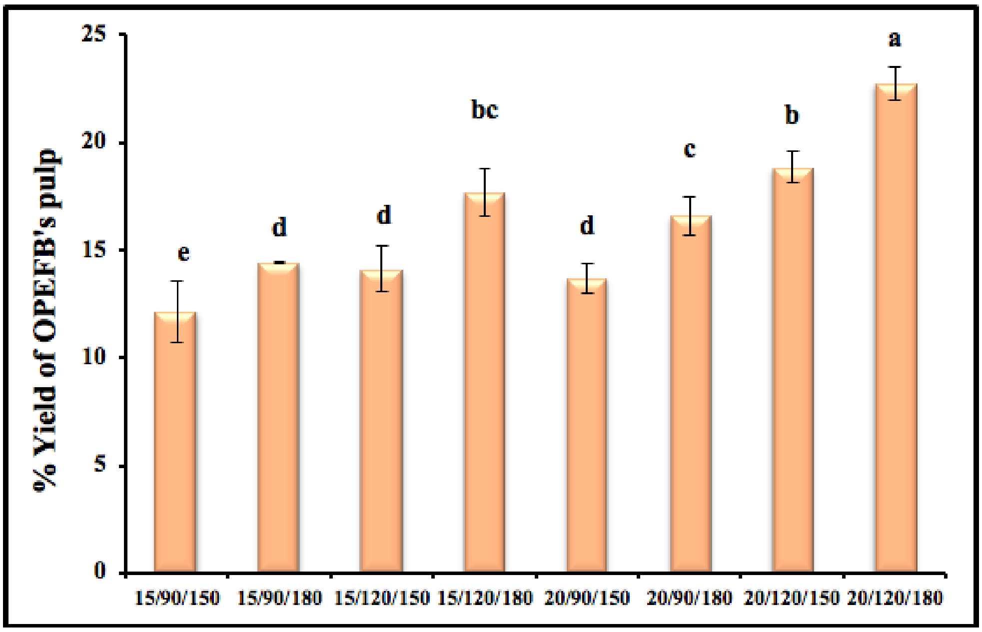

Figure 1. Pulp yields of OPEFB obtained from kraft pulping conditions.

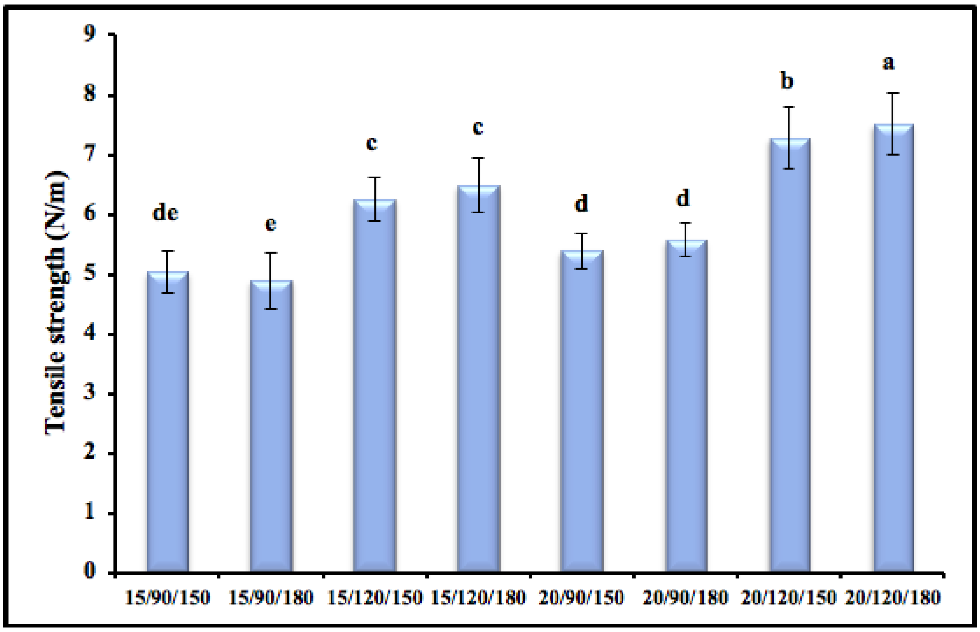

Figure 2. Tensile indices of pulp sheets obtained from kraft pulping process.

The trend of burst index (BI) was observed to be similar to that of the tensile index. Burst testing is the method to evaluate the behavior of paper when the perpendicular forces to the surface. It can indicate the rupture resistance of paper materials (Haslach, 2000). The pulp sheets of the kraft pulping condition of EA 20% (w/w), cooking time 90 minutes, and cooking temperature of 180°C (20/90/180) revealed the greatest burst index (BI) of 1.43 kP a.m^2/g. Nevertheless, the results similar to that of burst index (BI) obtained from the kraft pulping condition of EA 20% (w/w), cooking time 120 minutes, and cooking temperature of 180°C (20/120/180), shown in Figure 3.

A ring crush test is often used as a standard method for testing the compressive strength of corrugated container (Nordstrand, 2004). The ring crush indices (RCI) of pulp sheets obtained from the kraft pulping condition of EA20% (w/w), cooking time 120 minutes, and cooking temperature of 180°C (20/120/180) has the higher compressing force, in Figure 4. They contributed the highest RCI which was about0.22-0.27 Nm/g.Figure1, 2, 3, and 4 illustrates the relationship between the pulp yields of OPEFB and the mechanical properties of OPEFB's pulp sheets obtained from the kraft pulping process. It was found that the conditions the kraft pulping condition of EA20% (w/w), cooking time 120 minutes, and cooking temperature of 180°C (20/120/180) has better the mechanical properties than other conditions, then selected for preparation of pulp sheets for coated with the composite latex in the next step.

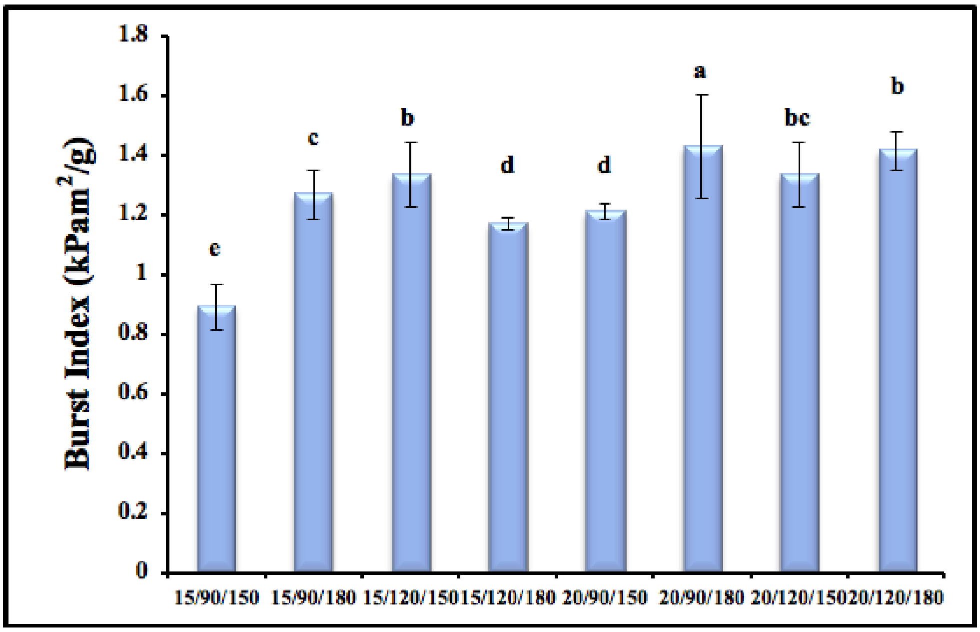

Figure 3. Burst indices of pulp sheets obtained from kraft pulping process.

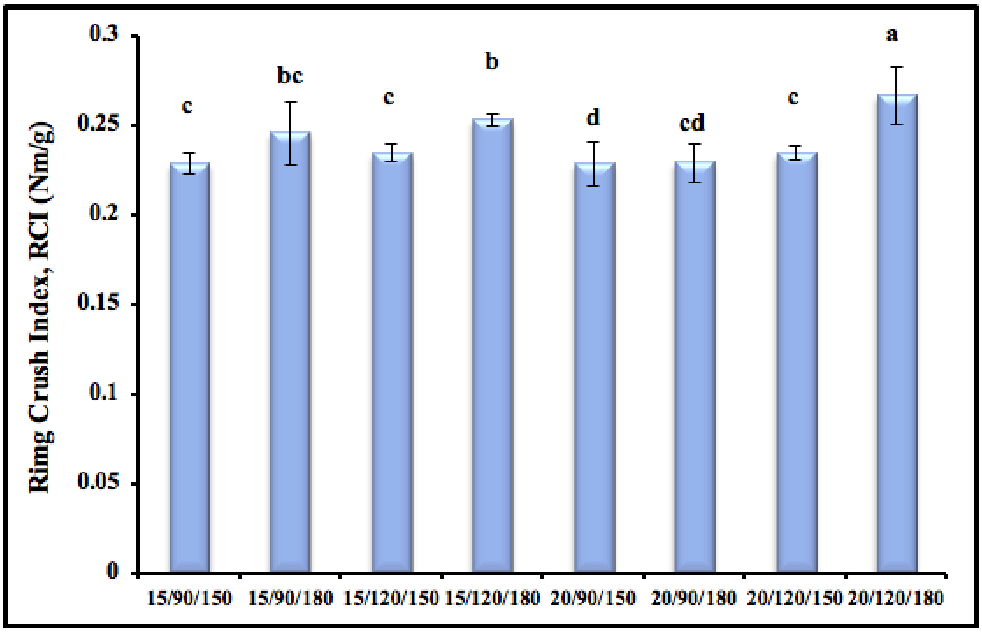

Figure 4. Ring crush indices of pulp sheets obtained from kraft pulping process.

Preparation and Testing of the coated OPEFB's pulp sheets

The appearances of coated OPEFB's pulp sheets were shown in Figure 5. The result showed that the 3rd formula of composite latex has a better appearance compared to other formulas. The surface of specimen with the 3rd formula was smooth and evenly while the others were rough and bubbly. The ability of deaeration in each coating formula was different due to the amount of wood resin dispersion. The distribution of wood resin will contribute to increasing the air bubbles in latex coating.The wood resin dispersion of each coating formula composed of bentonite which used as a surfactant. Bentonite is causing the coating surface roughness.

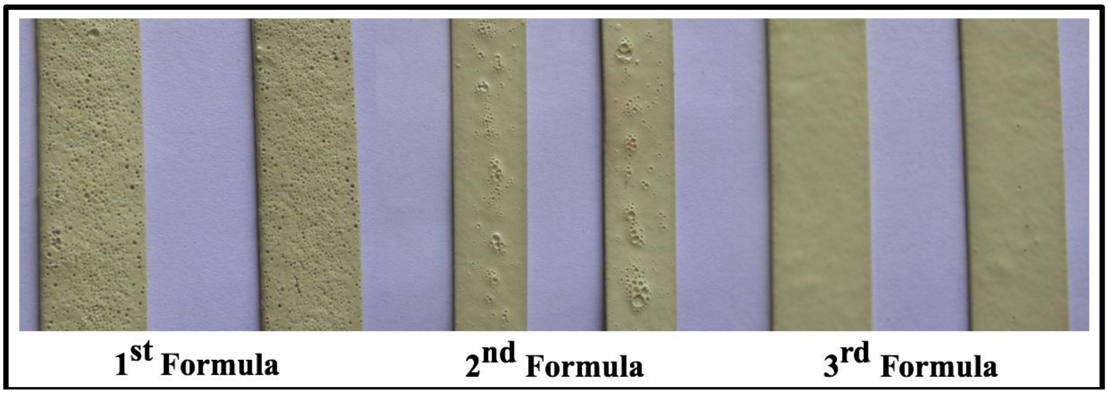

Figure 5. The appearance of coated OPEFB's pulp sheets withlatex coating.

Properties of coated OPEFB's pulp sheets

The mechanical properties of OPEFB's sheets coated and uncoated were investigated. Tensile strength of all coated specimens was lower than uncoated specimens because the water content in composite latex have broken the H-bonding of fiber network (shown in Figure 6). Furthermore, the results introduced that the different formulas of composite latex and coating time did not affect the tensile strength of coated specimens. Due to the formula of the three composite latex using the same level of soil the china clay as the reinforcement, the tensile strengths of coated specimens were not significantly different. On the other hand, the elongation at break of coated specimens was contrary to the tensile strength (shown in Figure 7). The coated specimens expressed the higher elongation comparing to the uncoated specimens. The coated specimen with the 3rd Formula of composite latex and 60seconds coating time(F3/S60) has the best elongation at break of 270mm. The composite latex coating increased the elasticity and flexibility of OPEFB's pulp sheets. This property is an advantage for the cushioning materials. However, the varied formulas and duration of coating have not effect to the elongation property of coated specimens due to the same level of SBR rubber in all formulas.

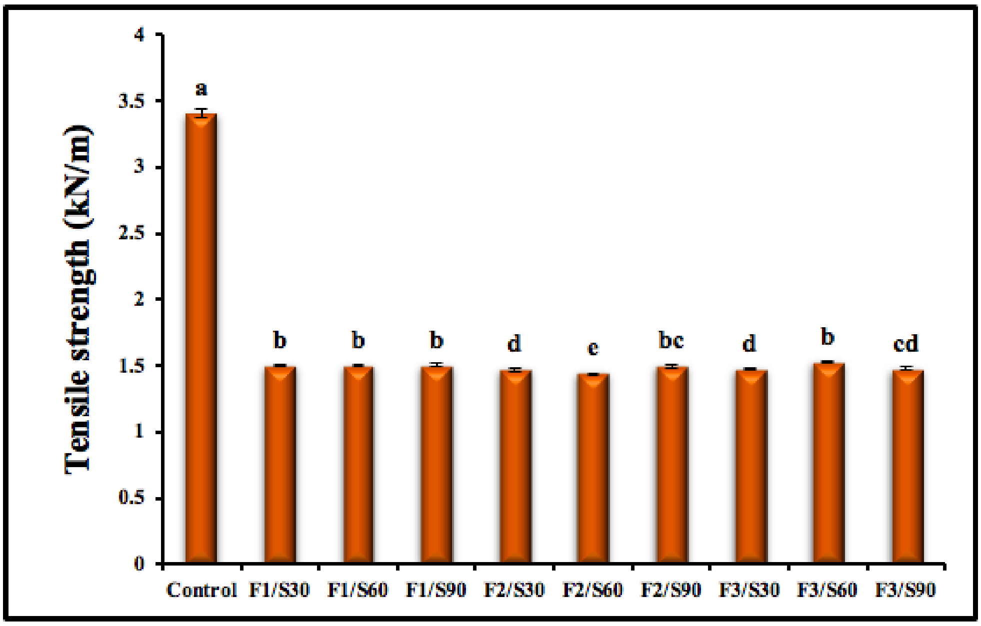

Figure 6.Tensile strength of the coated OPEFB's sheets at different coating conditions.

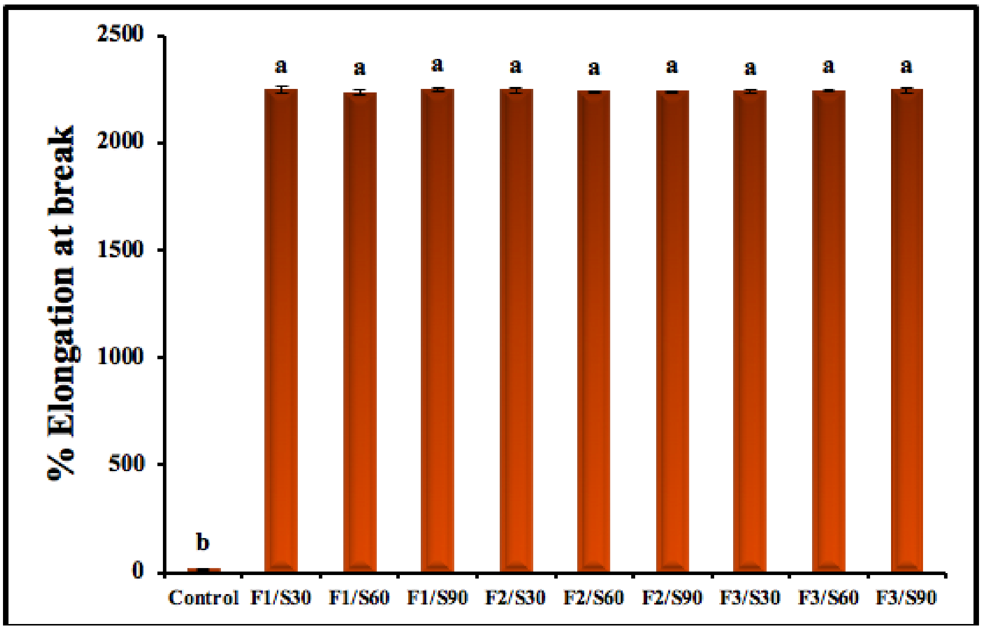

Figure 7. Elongation at break of the coated OPEFB's sheets at different coating conditions.

These results suggested that the coated specimen with the 3rd Formula of composite latex and 60seconds coating time (F3/S60) contributed the highest quality of latex coated pulp. It has been the best appearance and elongation.

Conclusions

High yield and good mechanical properties are the requirements of pulping in these research. The highest pulp yield of OPEFB's pulp was 22.78% (d.b.) which obtained from the kraft pulping condition of effective alkali 20% (w/w), cooking time 90 minutes, and cooking temperature of 180°C. This kraft pulping condition has the higher mechanical properties than other conditions. The pulp sheets of OPEFB could be improved the mechanical properties by coating with composite latex. The third formula having the lowest level of wood resin component provided the best appearance. The elongations at break of OPEFB's pulp sheets with composite latex coating were 150 times higher than OPEFB's pulp sheets without composite latex coating. The good resilience of pulp sheets made of OPEFB with composite latex coating indicated the ability of impact protection. It gives for a point of view with respect to further possibilitydevelopments.Therefore, it is the feasibility to apply the coated pulp sheets as a package-cushioning material.

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