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THE UTILIZATION OF KIWI (*ACTINIDIA DELICIOSA*) PRUNING WASTE FOR KRAFT PAPER PRODUCTION AND THE EFFECT OF THE BARK ON PAPER PROPERTIES

*In this study, samples of pruning residuals from kiwi (*Actinidia deliciosa*) with and without bark were used in order to identify the negative impacts of the bark on pulp and paper production. The Kraft method was used to cook the samples, and six tests were conducted, three with bark and three without bark. In the six tests, the active alkaline/sulfide ratios, temperature, and time were stabilized at 18/22, 170°C and 170 min, respectively. Some of the physical, optical, and mechanical properties of the unbeaten papers produced at 35 SR° and 50 SR° were compared. For all of the mechanical properties that were measured, the bark had a negative effect. This could be explained by the high content of brittle inorganic material in the bark's fibers.*

Keywords: Kiwi, *Actinidia deliciosa*, kraft process, bark, pruning waste

Introduction

The world's population is increasing rapidly, resulting in increased consumption of products and resources. Thus, the demand for wood as a raw material is increasing. Using solid wood for the production of fiber-based materials can increase the cost of the product. Therefore, it would be more economical to use non-wood or waste materials in the paper industry as much as possible. Waste materials which are used in the forest industry are lignocellulosic material waste and agricultural waste. The major non-wood products used in the production of pulp and paper are grain stalks, straws and bushes, and bark from wood. Usually bark is used for generating steam in plants, and this causes air pollution. The utilization of lignocellulosic waste can be more economical and more environmentally appropriate than discarding the waste, and many studies have been conducted in this area.

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Kalaycıoğlu and Nemli [2006] indicated that kenaf can be used to manufacture particleboard. González et al. [2011] showed that the prunings from orange trees can be used to obtain soda pulp of acceptable quality with yields from 34.10 to 51.81%. The annual yield in stalks after pruning is 5t/ha, which is greater than the average yield of forests in temperate zones [Ntalas, Grigoriou 2002]. Alaejos et al. [2006] studied Kraft, soda anthraquinone, and organosolv pulping methods for holm oak trimmings and indicated that the Kraft method was the best among these methods. Gençer et al. [2001] reported that medium density fiberboard (MDF) of standard quality should be made from whole cotton stalks. The investigation of the fibers, lignin, and cellulose content of the bark of cotton stalks indicated that the bark had high cellulose (79%) and low lignin (13.7%) and that single cells were shorter than those obtained from some other agricultural byproducts. Because of this advantage, the bark of cotton stalks is suitable for making lignocellulosic products [Reddy, Yang 2009]. Investigation of fiber dimensions and the lignin and cellulose content of various non-wood plants and agricultural residues, along with the use of certain indices, has shown that kenaf is suitable for producing paper of various grades, whereas reed, switchgrass, miscanthus, and cotton stalks are suitable for producing mainly writing and printing papers or mixing with conventional wood pulps to produce paper for various uses. The prunings from olive trees and almond trees have shorter and thicker fibers and produce relatively poor index values. The pulp from these species is expected to have relatively low mechanical strength, making it suitable only for replacing hardwood pulps in low or moderate proportions to produce newsprint or tissue paper [Ververis et al. 2004].

The kiwi plant is native to China, where it is grown to yield fruit in ecologically appropriate conditions; it is a fast-growing, clinging species [Haung, Ferguson 2001]. The prunings from kiwi plants generate an abundant, renewable, lignocellulosic residue, which is usually burned in the field to prevent the propagation of vegetal diseases which could incur economic costs and environmental concerns. Kiwi residue of any type must be taken out of the field, because dead and dry residues host disease and insects [Janie 1994]. Also, waste or pruning residues support more organisms than living plants [Paul, Clark 1989]. For this reason, kiwi prunings should be converted to more beneficial products. Nemli et al. [2003] found that the MOR of the particleboard for general purpose exceeded the minimum requirements according to the European standards when kiwi prunings contributed up to 50% of the material added to the core of the particleboard. The average fiber length, fiber width, lumen width, and fiber membrane thickness of kiwi (*Actinidia deliciosa*) are 1583.9, 35.97, 22.30, and 6.84 µm, respectively. Its felting ratio, elasticity coefficient, rigidity coefficient, Runkel ratio, and Mühlsteph ratio are 44.03, 61.99, 19, 0.61 and 61.58, respectively [Yaman, Gençer 2005]. Extremely long fibers cause formation defects in paper production. However, the resistance values of paper made of very short fibers are low. Therefore, fibers of trees with short and thin lamella are preferred.

With an average fiber length of 1583.9 μm, kiwi fibers are shorter than softwood fibers, but longer than hardwood fibers. Thus, kiwi fibers are advantageous for both fiber groups. The aim of the present study was to examine the effect of bark on kraft paper properties.

Materials and methods

The samples used in the experiment were obtained from Trabzon Province, located on the coast of the Eastern Black Sea region in Turkey. They were obtained at an altitude of 10 meters from the northern exposure. The kiwi samples were prepared in two groups, i.e., with and without bark, for the Kraft cooking process. The bark ratio over perfect dry sample weight was calculated in the pruning waste from which the bark had been removed, and then the samples were chipped manually. Following this, the moisture content of the chips was determined based on the oven-dry and air-dry weight. The samples were ground in a Wiley mill according to the TAPPI T 11 os-75 standard [1975]. This was followed by screening with the 60 mesh size, and the resulting material was used for chemical analysis. The TAPPI T 203 os-71 standard [1999] was used to determine the alpha cellulose; the TAPPI T 222 om-02 standard [2002] was used to determine the lignin content; the TAPPI T 207 cm-99 standard [1999] was used to determine the material's solubility in cold and hot water; and the TAPPI T 204 cm-97 [1997] standard was used to determine the material's solubility in alcohol.

Dry sample weights of 700 g for both types of chips were prepared and kept in polyethylene bags in the absence of air. The Kraft process was used in this study since it is suitable for all wood species in pulping. In addition, Vu et al. [2004] indicated that they found it to be the best cooking temperature for bamboo 165–170°C. The cooking conditions were based on values in literature, and a temperature of 170°C was used. The active alkali/sulfidity ratios were 18/22, and the cooking time was 170 min. Six cookings were conducted, including three replicates with bark and three without bark. The pulping process was electrically heated in a pressure-resistant, rotary boiler which revolved at a rate of two revolutions per minute. Unbeaten papers, at 35 SR° and 50 SR°, were made from the pulp which was obtained from the cooking, and the thickness, surface smoothness, air permeability, brightness, opacity, tearing index, burst index, and breaking length of each of the papers were determined. The experimental papers were subjected to the following tests after they were conditioned in an environmental test chamber with 65% relative humidity at a temperature of 23 ±1°C for 24 h, according to the TAPPI T402 om-88 standard.

Table 1. Physical, mechanical and optical tests conducted for kiwi (*Actinidia deliciosa*) paper

Experiment	Standard
Grammage	TAPPI 410 om-88
Thickness	TAPPI 411 om-89
Humidity	TAPPI 412 om-90
Cutting of trial papers	TAPPI 220 om-88
Tearing index	TAPPI 410 om-88
Breaking length	TAPPI T494 om-01
Air permeability	ISO 5636-3
Surface smoothness	ISO 8791-2
Burst index	TAPPI 403 om-91
Opacity	TAPPI T519 om-02
Brightness value	TAPPI T525 om-02

The ”Statgraphics Plus for Windows 3.1” software package was used in this study. Variance analysis test was used to determine the differences among the treatments, and also Duncan test was used to determine the which one had the best effect.

Results and discussion

In this study, the average kiwi plant bark ratio was calculated to be approximately 22% according to the oven-dry weight of the raw material from the kiwi prunings. Reddy and Yang [2009] investigated the bark content of cotton stalks, and they found that the outer bark comprised approximately 20% of the weight of the cotton stalk. Domingues et al. [2011] investigated the extraction yields of the bark of several eucalyptus species, and they found that the outer bark extraction yield was higher than the inner bark. Some chemical and physical features of kiwi (*Actinidia deliciosa*) wood are given in table 2.

Table 2. Chemical and physical features of kiwi (*Actinidia deliciosa*) wood

Experiment	Ratio [%]
Chip moisture	9.55
Alcohol Solubility	2.01
Holocellulose	73.50
Alpha Cellulose	38.30
Lignin	25.26

The holocellulose content of the kiwi is approximately equal to that of the hardwoods, which indicates that kiwi should give a fairly high yield of pulp when cooked properly. Table 3 shows the screened yield, screenings, and total yield of the pulp obtained from the prunings of kiwi plants with and without bark.

Table 3. Kiwi (*Actinidia deliciosa*) pulp yield

Sample	Screened Yield [%]	Reject [%]	Total Yield [%]	Kappa Number
Without bark	44.39	1.48	45.87	17
With bark	38.50	3.44	41.94	19

In this study, the total yield from the samples without bark was found to be 45.87%, which was greater than the yield of the samples with bark. The pulp yields from olive tree wood obtained by soda, sulfite, and kraft pulping were 44.9, 43.1, and 41.9%, respectively [López et al. 2000]. Some physical, mechanical, and optical values of the papers produced at different SR° are given in table 4.

Table 4. Physical, mechanical and optical features of the papers produced from kiwi wood with and without bark at different SR°

SR°		Test sample	S.v.	Physical properties			Optical properties		Mechanic properties		
				thickness [µm]	S.s. [ml/min]	A.p. [ml/min]	opacity [%]	brightness [%]	tear index [Nm.m^2/g]	B.l. [km]	B.i. [kPa.m^2/g]
Unbeaten	15	with Bark	$\overline{x}$	166.00A	830.60A	>5000A	99.89A	16.84A	1.80A	18.29A	0.74A
			±s	2.51	51.31	0	0.11	0.02	0.12	0.73	0.34
	26	debarked	$\overline{x}$	163.00B	866.00A	>5000A	99.88A	19.35B	2.01A	18.36 A	0.81A
			±s	2.05	61.16	0	0.05	0.07	0.34	0.41	0.19
35		with Bark	$\overline{x}$	107.25C	529.30C	206.35C	99.85C	15.23C	3.78C	50.28C	2.56C
			±s	3.02	50.98	24.06	0.14	0.13	0.11	1.49	0.11
		debarked	$\overline{x}$	103.25D	553.15C	131.70D	99.69D	17.21D	4.87D	60.03D	3.05D
			±s	2.94	129.01	8.13	0.14	0.07	0.08	2.45	0.12
50		with Bark	$\overline{x}$	101.00 E	382.90E	105.25E	99.79E	14.19E	3.89E	58.11E	2.87E
			±s	3.48	22.04	9.44	0.11	0.20	0.17	2.80	0.16
		debarked	$\overline{x}$	97.25 F	385.00E	92.5F	99.45F	15.05F	3.97E	68.13F	3.42F
			±s	2.55	18.06	2.06	0.16	0.37	0.05	2.61	0.16

$\overline{x}$ = Average, ±s = Standard deviation
S.v.: Statistical values, S.s.: Surface smoothness, A.p.: Air permeability, B.l.: Breaking length, B.i.: Bursting index

The Duncan test was conducted to determine the physical, optical and mechanical features of the papers produced from kiwi (*Actinidia deliciosa*), and the results are shown in table 4. According to these results, the values within the 95% confidence interval are shown at unbeaten, 35 and 50 SR° pulp with A and B, C and D, E and F, respectively.

Khristova et al. [2006] found the alpha cellulose value of bagasse to be 51.90% and Gümüşkaya et al. [2007] found the alpha cellulose value of hemp (*Cannabis sativa* L.) bast fibers to be 63.77% and the value of holocellulose to be 86.93%. Deniz et al. [2004] found the alpha cellulose value of wheat straw to be 38.20%, the holocellulose value to be 74.50% and the lignin value to be 15.30%. The alpha cellulose value determined in this study was 38.30%, while the holocellulose value was 73.50%; these values were similar to the wheat straw values given above. The average lignin ratio was reported to be 28 ±3% in softwood and 20 ± 4% in hardwood [Suchsland, Woodson 1986]. The lignin ratio of kiwi was 25.26%, between those of softwood and hardwood. Despite being in brush form, kiwi had the high lignin values as the trees, therefore it is believed that the amount of alkaline used in the study was appropriate considering the lignin ratio. The kappa number of kiwi pulp samples without bark was found to be 17 and for the samples with bark it was 19. The yield and kappa number are inversely proportional, and therefore this can be explained by the bark having a higher lignin and extractive content. Vu et al. [2004] studied bamboo and they found that the lignin ratio was 25.8%, the EA was 18%, and the kappa number was 18.6 at 15% sulfidity. They also reported that increasing sulfidity did not decrease the kappa number significantly.

The thickness, surface smoothness, air permeability, brightness, and opacity values of the papers obtained from the pulp with and without bark decreased as the beating degree increased. The burst index and breaking length increased. The tearing index increased at the beginning of the beating and decreased later. These results were the expected outcomes of beating.

In making bleached Kraft pulp from hardwoods, the acceptable amount of bark was determined to be 5% [Kırcı 2003]. The average bark ratio according to the full dry raw material weight in the kiwi pruning waste in this study was calculated as 22.20%. Although the amount of bark was well above the acceptable tolerance level, the physical, mechanical and optical values of papers with bark were affected to a small extent, excluding air permeability and breaking length. The likely reason was that kiwi's bark is softer than the barks of other trees. In this study, the pulp yield of the samples without bark was 45.87%, which was better than those with bark. One reason for this was that the screenings in the samples with bark were high, and another reason was that the rate of extractives and non--fibrous materials in the structure of the bark was relatively high compared to wood.

Physical properties

The handsheet thickness of the papers at different SR° decreased as the beating degree increased. The handsheet thickness of the samples without bark was less than that of the samples with bark at unbeaten, 35 and 50 SR°, and the difference was significant at the 95% confidence level. This was because the fibrous structure of the bark was more voluminous. The surface smoothness value decreased as the beating degree increased. However, this decrease was inversely proportional to numerical values from the rough surface towards the smooth surface. Therefore, the surface smoothness improved as the beating degree increased. The surfaces of the samples without bark were smoother than those with bark at different SR°. However, the difference was not significant at the 95% confidence level. This result was expected because the fibrous structure of the bark, which is rougher than that of wood. Since the air permeability of the unbeaten papers was over 5000 ml/min, it was considered to be non-standard. The air permeability value decreased as the degree of beating increased. The air permeability of the samples with bark at 35 and 50 SR° was significantly greater than that of the samples without bark, and the difference was significant at the 95% confidence level. The fact that the porosity of the bark was very high compared to that of wood increased the difference between the air permeability values.

Optical properties

The opacity value was directly related to the light transmittance of the paper, and it increased as the colour of the paper darkened. The opacity of unbeaten pulps was found to be higher than that of the debarked pulps but the difference was not found to be statistically significant. The opacity value of the papers decreased as the beating degree in the papers increased. Because of the dark colour of the bark, the opacity values of the samples with bark were greater than those of the samples without bark, 35 and 50 SR°, and the difference was significant at the 95% confidence level. The brightness value was directly related to the opacity feature of the paper.

The white colour was significantly more reflective than the black, which absorbed the light. The b rightness value decreased as the beating level increased. Therefore, the brightness value was found to be greater in the samples without bark at unbeaten 35 and 50 SR°, and the difference was significant at the 95% confidence level.

Mechanical Properties

The mechanical properties increased in direct proportion to the fibers' stiffness and length. The tearing index of the papers increased at the beginning of the beating and decreased towards the end of the beating. The tearing index of the pulps with bark was found to be lower than the unbeaten, 35 and 50 SR° and the difference was found to be statistically significant at the 95% confidence level.

The tearing index at unbeaten (2.01 Nm m^2/g) of the kiwi wood paper fibers without bark was greater than that of the samples with bark (1.80 Nm m^2/g), while the tearing index at 50 SR° (3.97 Nm m^2/g) of the kiwi wood paper fibers without bark was greater than that of the samples with bark (3.88 Nm m^2/g), but the difference was not significant at the 95% confidence level because some of the bark was removed after screening. The tearing index at 35 SR° (4.87 Nm m^2/g) of the kiwi wood paper fibers without bark was greater than that of the samples with bark (3.78 Nm m^2/g), and the difference was significant at the 95% confidence level. The breaking length increased as the beating degree increased. The breaking length of the samples with bark was found to be lower than the unbeaten, 35 and 50 SR° pulps and the difference was found to be statistically significant at the 95% confidence level. Finally, the burst index was found to be greater at 35 and 50 SR° and the difference was significant.

Jiménez et al. [2006] used vine shoots in different pulping processes, and found that the Kraft process provided paper with better breaking length (13.16 km), burst index (1.63 kPa m^2/g), and tear index (1.59 Nm m^2/g) than samples without bark, which had a breaking length of 68.13 km and a burst index of 2.61 kPa m^2/g. In this study, it was found to be higher in samples with bark (58.10 km and 2.87 kPa m^2/g) and the difference between them was significant at 5% confidence interval. However, bark up to 20% was reported to have no effect on the strength of Kraft (Douglas fir) pulps [Casey 1961]. Mutjé et al. [2005] found that sheets from olive prunings that were obtained by means of an organosolv process had a burst index of 3.02 kPa m^2/g. The burst test is very important in sack papers, packing papers, and paperboard for packs. High breaking strength increases resistance against breakage in the printing press. Therefore, it is important in newspaper and other printing paper [Casey 1961]. Since bark lowers the burst index, the papers obtained from samples with bark should not be used in producing sack papers, packing papers, and paperboard for packs. In addition, paper obtained from samples with bark can be used in newspaper and other printing paper.

Conclusions

The fibrous material ratio of the bark was relatively low compared to wood. Therefore, the chips put into the cooking tank should not have bark. It occupies a larger volume and consumes more chemical materials during cooking. However, it might not always be very economical to completely debark the raw material. Bark tolerance could be high in some pulp types. Still, most of the wood bark in this pulp should also be removed. For the types of pulp in which bark does not cause problems, paper can be produced from kiwi prunings with bark. This eliminates the cost of debarking. Pulp making with and without bark should then be decided based on an economical analysis.

The kiwi plant is not very widespread in Turkey. However, growing kiwi has recently become more common in the Black Sea region. Since kiwi is pruned every year, the waste raw material potential of the plant is high. Besides this, since its cellulose ratio is high, it can be used for pulp production. In this study, the Kraft method was used. However, by trying other chemical, semi-chemical, and mechanical methods, more precise decisions on the advisability of using kiwi wood for pulp production can be made.

Pruning waste obtained from the kiwi plant is a sustainable fiber source since the plants are pruned annually. This waste should be utilized in the pulp and paper industry in order to provide income for growers.

References

Alejos J., Lopez F., Eugenio M.E., Tapias R. [2006]: Soda-anthraquinone, kraft and organosolv pulping of holm oak trimmings. Bioresource Technology 97 [16]: 2110–2116

Casey J.P. [1961]: Pulp and Paper Chemistry and Chemical Technology III. New York: 1029–1063

Domingues R.M.A., Sousa G.D.A., Silva C.M., Freire C.S.R., Silvestre A.J.D., Pascoal Neto C. [2011]: High value triterpenic compounds from the outer barks of several Eucalyptus species cultivated in Brazil and in Portugal. International Crops and Products 33 [1]: 158–164

Deniz İ., **Kırcı H., Ates S.** [2004]: Optimisation of wheat straw Triticum drum kraft pulping. Industrial Crops and Products 19 [3]: 237–243

Gençer A., Eroğlu H., Özen **R.** [2001]: Medium density fiberboard manufacturing from cotton stalks. Inpaper International 5 [2]: 26–28

Gonzáles Z., Rosal A., Requejo A., Rodríguez A. [2011]: Production of pulp and energy using orange tree prunings. Bioresource Technology 102 [19]: 9330–9334

Gümüşkaya E., Usta M., Balaban M. [2007]: Carbohydrate components and crystalline structure of organosolv hemp (*Cannabis sativa* L.) bast fibers pulp. Bioresource Technology 98 [3]: 491–497

Haung H., Ferguson A.R. [2001]: Kiwi fruit in China. New Zealand Journal of Crop and Horticultural Science 29: 1–14

Janie K.H. [1994]: Kiwifruit and Handling. UCANR Publications: 132–134

Jiménez L., Angulov V., Ramos E., De La Torre M.J., Ferrer J.L. [2006]: Comparison of various pulping processes for producing pulp from vine shoots. International Crops and Products 23 [2]: 122–130

Kalaycıoğlu H., Nemli G. [2006]: Producing composite particleboard from kenaf (*Hibiscus cannabinus* L.) stalks. International Crops and Products 24 [2]: 177–180

Khristova P., Kordsachia O., Patt R., Karar I., Khider T. [2006]: Environmentally friendly pulping and bleaching of bagasse. Industrial Crops and Products 23 [2]: 131–139

Kırcı H. [2003]: Pulp Industry. Karadeniz Technical University Faculty of Forestry Publishing No: 72,Trabzon

López F., Ariza J., Pérez I., Jiménez L. [2000]: Comparative study of paper sheet olive tree wood pulp obtained by soda, sulphite, or kraft pulping. Bioresource Technology 71 [1]: 83–86

Mutjé P., Pèlach M.A., Vilaseca F., García J.C., Jiménez L. [2005]: A comparative study of the effect of refining on organosolv pulp from olive trimmings and kraft pulp from eucalyptus wood. Bioresource Technology 96 [10]: 1125–1129

Nemli G., Kırcı H., Serdar B., Ay N. [2003]: Suitability of kiwi (*Actinidia Sinensis* Planch.) prunings for particleboard manufacturing. Industrial Crops and Products 17 [1]: 39–46

Ntalas G.A., Grigoriou A.H. [2002]: Characterization and utilization of vine prunings as a wood substitute for particleboard production. Industrial Crops and Products 16 [1]: 59–68

Paul E.A., Clark F.E. [1989]: Soil Microbiology and Biochemistry. Academic Press, Elsevier Science

Reddy N., Yang Y. [2009]: Properties and potential applications of natural cellulose fibers from the bark of cotton stalks. Bioresource Technology 100 [14]: 3563–3569

Suschland O., Woodson G.E. [1986]: Fiberboard Manufacturing Practices in the United States. Agriculture Handbook No. 640. United States Department of Agriculture, Forest Service

Ververis C., Georghiou K., Christodouulakis N., Santas P., Santas R. [2004]: Fiber dimensions, lignin and cellulose of various plant materials and their suitability for paper production. Industrial Crops and Products 19 [3]: 245–254

Vu T.H.M., Pakkanen H., Alén R. [2004]: Delignification of Bamboo (*Bambusa procera acher*) Part 1. Kraft Pulping and the Subsequent Oxygen Delignification to Pulp with a Low Kappa Number. Industrial Crops and Products 19 [1]: 49–57

Yaman B., Gençer A. [2005]: Fiber Morphology of Kiwi (*Actinidia deliciosa* (A. Chev.) C. F. Liang and A.R. Ferguson) Grown in Trabzon. Süleyman Demirel University Faculty of Forestry Journal Seria: A [2]: 149–155

List of standards

ISO 5636-3:2009 Air permeability

ISO 8791-2:2009 Surface smoothness

TAPPI 220 sp-01:2001 Physical testing of pulp handsheets

TAPPI 403 om-02:2002 Bursting strength of paper

TAPPI 410 om-02:2002 Grammage of paper and paperboard (weight per unit area)

TAPPI 411 om-97:1997 Thickness (caliper) of paper, paperboard, and combined board

TAPPI 412 om-02:2002 Moisture in pulp, paper and paperboard

TAPPI 414 om-98:1998 Internal tearing resistance of paper (Elmendorf-type method)

TAPPI T 11 os-75:1975 standard

TAPPI T 203 cm-99:1999 Alpha-, beta- and gamma-cellulose in pulp

TAPPI T 204 cm-97:1997 Solvent extractives of wood and pulp

TAPPI T 207 cm-99:1999 Water solubility of wood and pulp

TAPPI T 222 om-02:2002 Acid-insoluble lignin in wood and pulp

TAPPI T 494 om-01:2001 Tensile Properties of Paper and Paperboard (Using Constant Rate of Elongation Apparatus)

TAPPI T 519 om-02:2002 Diffuse Opacity of Paper (d/0 paper backing)

TAPPI T 525 om-02:2002 Diffuse Brightness of Pulp (d/0)