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Characterization of Pulp and Paper Properties Produced from Okra (*Abelmoschus esculentus*) Stalks

Karakterizacija pulpe i papira izrađenih od stabljika bamije (*Abelmoschus esculentus*)

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ABSTRACT • *In this study, the usability of okra (Abelmoschus esculentus) stalks in pulp and paper production was investigated. Firstly, chemical components and fiber morphological properties were determined to investigate the suitability of okra stalks for pulp and paper production. Holocellulose, cellulose and lignin contents were found as 76.1 %, 46.4 % and 16.0 %, respectively and the fiber length, fiber width and cell wall thickness were measured as 0.64 mm, 16.97 µm and 3.66 µm, respectively. According to these data, it has been determined that okra stalks are suitable for pulp and paper production. Four different cooking experiments were carried out by adding sodium borohydride ($NaBH_4$) in different proportions (0 %, 0.3 %, 0.5 %, 0.7 %) to okra stalks by the alkali sulfite method. The yield, chemical, physical and optical properties of the pulps were determined and optimum properties were obtained from the cooking experiment by adding up to 0.7 % $NaBH_4$ into cooking liquor. With the addition of 0.7 % $NaBH_4$, pulp yield, breaking length, and burst index increased about 7.73 %, 3.84 %, and 11 %, respectively. Consequently, it has been concluded that pulp produced from okra stalks can be used in the paper industry by blending with long or recycled fibers in certain proportions.*

KEYWORDS: *okra stalk; pulp; paper; $NaBH_4$*

SAŽETAK • *U ovom je radu istraživana upotrebljivost stabljika bamije (Abelmoschus esculentus) za proizvodnju celuloze i papira. Radi ispitivanja prikladnosti stabljika bamije za proizvodnju celuloze i papira, najprije su određeni udjeli kemijskih komponenata i morfološka svojstva vlakana. Utvrđeni udjeli holoceluloze, celuloze i lignina iznosili su 76,1 %, 46,4 % i 16,0 %. Duljina vlakana, širina vlakana i debljina stanične stijenke bili su 0,64 mm, 16,97 µm i 3,66 µm. Prema tim podatcima utvrđeno je da je stabljika bamije pogodna za proizvodnju celuloze i papira. Zatim su provedena četiri različita pokusa kuhanja alkalno sulfitnim postupkom, uz varijabilni dodatak natrijeva borhidrida ($NaBH_4$): 0 %; 0,3 %; 0,5 %; 0,7 % s obzirom na količinu stabljika bamije. Određeni su prinos pulpe, njezina kemijska, fizikalna i optička svojstva te su postignuta optimalna svojstva pulpe u procesu kuhanja uz dodatak 0,7 % $NaBH_4$ smjesi kemikalija za kuhanje (bijeli lug). Uz dodatak 0,7 % $NaBH_4$, prinos pulpe, duljina loma i indeks pucanja papira izrađenoga od vlakana bamije povećali su se za oko 7,73 %, 3,84 %, odnosno 11 %. Posljedično, zaključeno je da se pulpa proizvedena od stabljika bamije može upotrebljavati u industriji papira u određenim omjerima pomiješana s dugim ili recikliranim vlaknima.*

KLJUČNE RIJEČI: *stabljika bamije; pulpa; papir; $NaBH_4$*

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1 INTRODUCTION
1. UVOD

The decline in forest areas led the forest products industry to find new raw materials in the second half of the 20th century, particularly with the increase in global population and the increase in demand for forest products due to rapid technological developments (Oner and Aslan, 2002; Tutuş *et al.*, 2011; Birinci *et al.*, 2020). There are various cellulosic raw materials in the pulp and paper production. The most important of these is the wood. If the insufficiency in raw materials is considered to be a major problem of the present and the future, the focus should be placed on annual plants for the production of pulp and paper (Kaldor, 1992; Comlekcioglu *et al.*, 2016; Tutuş *et al.,* 2016a).

Flax, cotton, bamboo and cereal stalks have been widely used in the pulp and paper production as non-wood plants and agricultural residues. Okra (*Abelmoschus esculentus*) stalks might be one of the promising plants for the production of non-woody paper (Jimenez *et al.*, 2008; Rodriquez *et al.*, 2010). The okra (*Abelmoschus esculentus*) and cotton (*Gossypium hirsutum*) families are Malvaceae. Okra is one of the earliest cultivated crops, recorded by the Egyptians in 1216 AD, but strong evidence has been obtained that okra was grown earlier in Ethiopia and some other reports considered India to be the center of its origin (Lamont, 1999; Singha *et al.*, 2014; Tong, 2016). According to the Food and Agriculture Organization of the United Nations (FAO), approximately 9.95 million tons of okra were produced in the world in 2019 (Faostat, 2021). As a result of negotiations with okra farmers, 2 kg of okra stalk is obtained in the production of 1 kg of okra and this amount will have an important place in the wood products industries, especially in the pulp and paper industry where an alternative to wood is sought. Atik has utilized okra stalks to produce pulp and paper using the soda-AQ (anthraquinone) method and reported that good pulp could be produced from okra stalks (Atik, 2002). It has previously been observed that pulps produced from okra stalks are suitable for the production of writing and printing paper and that different types of paper can be produced by blending with other pulps (Omer *et al.,* 2019). Comparing soda-AQ and kraft pulping methods for obtaining okra stalk pulp showed that the kraft process is suitable for okra stalk pulping and that kraft pulp showed better bleachability than soda-AQ pulp (Jahan *et al.,* 2012).

Various studies have been conducted to improve the performance, yield and strength of the pulp by adding different chemicals to the conventional cooking liquor (Akgül and Temiz, 2006; Istek and Özkan, 2008; Gülsoy and Eroglu, 2011; Tutuş *et al*., 2011; Tutuş *et al*., 2015; Tutuş and Çiçekler, 2016; Akgül *et al*., 2018). These studies were generally done to stop or reduce the peeling reaction that occurs during cooking. Anthraquinone and boron compounds are commonly used for this purpose. Many studies have been conducted investigating the effect of sodium borohydride ($NaBH_4$) additive, one of the boron compounds, on the pulp and it has been reported that it has a positive effect on the pulp (Pettersson and Rydholm, 1961; Meller, 1963; Khaustova *et al*., 1971; Akgül and Temiz, 2006; Istek and Özkan, 2008; Tutuş *et al*., 2012). Since $NaBH_4$ is a strong reducer, it prevents yield losses in the cooking environment. During the cooking process, $NaBH_4$ reduces the carbonyl group at the reducing ends of the cellulose chain to a hydroxyl group and prevents the peeling reaction that may occur. This reaction occurs not only in cellulose, but also in hemicelluloses. Therefore, the yield loss caused by the peeling reaction is prevented and the yield of the pulp obtained is increased (Akgül and Temiz, 2006; Istek and Özkan, 2008).

Due to the shortage of raw materials in the paper industry, it has been important in recent years to achieve maximum efficiency and quality with new raw materials in pulp production. This study focused on investigating the usability of okra stalks as an alternative raw material to wood and other non-wood lignocellulosic materials in pulp and paper production.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Material
2.1. Materijali

The okra stalks used in the study were obtained from Kahramanmaraş-Turkey after harvest. The stalks were removed from their shells and impurities and chipped at a size of about 4-6 cm, suitable for pulp production.

2.2 Chemical components and fiber morphology determination
2.2. Određivanje udjela kemijskih komponenata i morfologije vlakana

A sufficient amount of air-dried samples to be used in the chemical analysis was ground in a laboratory type Wiley mill according to the TAPPI T257 standard method and sieved in 40 mesh (425 μm) and 60 mesh (250 μm) vibrating sieves. The part that passed through a 40 mesh sieve and remained on the 60 mesh sieve was taken and put into glass jars with lids and prepared to be used in chemical analysis. Then, the samples were subjected to the following chemical analysis: holocellulose (Wise and Karl, 1962), cellulose (Kürschner and Hoffer, 1969), alpha cellulose (TAPPI T203), lignin (TAPPI T222), ethanol-toluene solubility (ASTM D1107), ash content (TAPPI T211), water (TAPPI T207) and 1 % NaOH (TAPPI T212) solubilities. For each experiment, three repetitions were performed, and mean data were used.

The length, lumen diameter, and width of the fibers included in the structure of the morphological parts of the okra stalks are important in terms of paper production. In the preparation of the slides, the chloride maceration method was used to individualize the fibers. Permanent slides were then prepared from the macerated fibers using a glycerin-gelatin solution. In the measurements of fiber morphology; fiber length, lumen diameter and fiber widths were determined by using Nikon FS1 photo microscope (Kılıç Ak *et al.,* 2021). At least 100 measurements were made for each fiber dimension. Thereupon, the fiber parameters were calculated using a previously described procedure (Comlekcioglu *et al*., 2016) by Eqs. 1-4 given below.

$$Felting\ ratio = \frac{Fiber\ length}{Fiber\ diameter} \quad (1)$$

$$Elasticity\ coefficient\ (\%) = \frac{Lumen\ diameter}{Fiber\ diameter} \cdot 100 \quad (2)$$

$$Rigidity\ coefficient\ (\%) = \frac{Cell\ wall\ thickness}{Fiber\ diameter} \cdot 100 \quad (3)$$

$$Runkel\ ratio = \frac{Cell\ wall\ thickness \cdot 2}{Lumen\ diameter} \quad (4)$$

2.3 Pulp production from okra stalks
2.3. Proizvodnja pulpe od stabljika bamije

Cooking processes were carried out in a laboratory type rotary cylindrical digester with a capacity of 15 liters, electrically heated, resistant to a pressure of 25 bar, capable of 4 revolutions per minute, whose temperature can be controlled by thermostat with an automatic control table. The filling of the raw material and unloading of the pulps were done by hand, and 500 grams oven-dried dry okra stalks chips were used in each cooking. Four cooking experiments were carried out under the cooking conditions listed in Table 1.

The pulps obtained at the end of each cooking were washed on a 200 mesh screen with plenty of tap water until the black liquor was removed. After the chemical substances were removed by washing, it was disintegrated in a laboratory type pulp disintegrator for 10 minutes at a certain concentration, and the uncooked parts were separated by a vibrating screen with a slit opening of 0.15 mm. The kappa numbers and viscosity values of the screened pulps were determined according to TAPPI T236 and TAPPI T230, respectively.

2.4 Paper production and tests
2.4. Izrada papira i ispitivanje njegovih svojstava

The pulp obtained from okra stalks was beaten gradually in a Hollander device up to (35±5) SR° degree. The moisture content of the beaten pulps was determined and the pulp was converted into paper weighting approximately (70±2) g/m^2 in a semi-automatic Regmed RK-21 device. The test papers were conditioned in a conditioning room at (23±1) °C and a relative humidity of (50±2) % for 24 h according to TAPPI T402, after which they were physically and optically tested. The brightness was measured according to ISO 2470-1 as the optical property of the papers. The breaking length and burst index were determined in accordance with the standards TAPPI T494 and TAPPI T403, respectively, as the physical properties. Variance and Duncan tests have also been used to show the influence of $NaBH_4$ on the physical and optical characteristics of the paper.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Chemical components and fiber morphology properties of okra stalks
3.1. Udjeli kemijskih komponenata i morfološka svojstva vlakana od stabljika bamije

The chemical components of okra stalks and some annual plants and types of wood are given for comparison in Table 2 below.

The holocellulose and cellulose contents of okra stalks were determined as 76.1 % and 46.4 %, respectively. These analyzed components have a similar val-

Table 1 Cooking conditions applied to okra stalks
Tablica 1. Parametri kuhanja stabljika bamije

Pulping condition / *Uvjeti kuhanja*	**Unit** / *Jedinica*	**Value** / *Vrijednost*
NaOH charge / *udio NaOH*	%	20
Na_2SO_3 charge / *udio* Na_2SO_3	%	15
$NaBH_4$ charge / *udio* $NaBH_4$	%	0, 0.3, 0.5, 0.7
Cooking temperature / *temperatura kuhanja*	°C	160
Time to maximum temperature / *vrijeme potrebno za postizanje maksimalne temperature*	min	140
Time at maximum temperature / *vrijeme kuhanja na maksimalnoj temperaturi*	min	110
Liquor to raw material ratio / *odnos tekućih komponenata i krute sirovine*	l/kg	5/1

Table 2 Main chemical components of okra stalks, annual plants and types of wood
Tablica 2. Glavne kemijske komponente stabljika bamije, jednogodišnjih biljaka i drva

Annual plants and wood species *Drvenasta vrsta*	**Holocellulose** *Holoceluloza, %*	**Cellulose** *Celuloza, %*	**Alpha cellulose** *Alfa-celuloza, %*	**Lignin** *Lignin, %*	**Ash** *Pepeo, %*	**Ethanol-toluene solubility** *Topljivost u smjesi etanola i toluena, %*	**1% NaOH solubility** *Topljivost u 1 %-tnoj otopini NaOH, %*	**Hot water solubility** *Topljivost u vrućoj vodi %*	**Cold water solubility** *Topljivost u hladnoj vodi %*	**Literature** *Literatura*
Okra stalks (Std. Deviation) *stabljike bamije (stand. devijacija)*	76.1 (0.37)	46.4 (0.16)	37.8 (0.12)	16.0 (0.27)	4.90 (0.12)	6.40 (0.02)	37.1 (0.40)	17.5 (0.03)	17.9 (0.39)	Current study *Ovo istraživanje*
Poppy stalks *stabljike maka*	79.8	40.9	51.7	19.2	4.70	-	30.4	10.4	5.10	Tutuş *et al.*, 2011
Cotton stalks *stabljike pamuka*	75.6	45.5	39.8	18.2	2.50	6.10	30.9	14.3	11.7	Tutuş *et al.*, 2010
Wheat stalks *slama žitarica*	77.6	52.5	40.2	17.3	7.10	5.50	42.1	13.0	9.00	Tutuş and Çiçekler, 2016
Softwood *meko drvo*	63-74	55-61	-	25-32	0.2-0.5	1-5.8	8-10	1-5	0.5-4	Kirci, 2006
Hardwood *tvrdo drvo*	72-82	38-55	-	18-26	0.2-0.7	1-6.2	12-25	1-8	0.2-4	Kirci, 2006

ue to hardwood and annual plants. Alpha cellulose content of okra stalks was slightly lower than that of other species. Lignin, which is one of the important components in terms of ease and economy of pulp production, was found to be lower than that of other lignocellulosic species. The ash content (4.9 %) was determined at similar rates with annual plants listed in Table 2. Although the high NaOH solubility rate is due to low molecular weight carbohydrates and other soluble alkaline substances, the high rate of fungal rot in okra stalks also affects it (Tutuş *et al.,* 2016b). When the chemical components of okra stalks are examined, it is understood that they are generally in harmony with the literature as seen in Table 2. The components that are important in pulp and paper production are holocellulose and cellulose (Smook, 1992; Tutuş and Çiçekler, 2016; Tutuş *et al.,* 2016b) in terms of yield, and these values are at the desired level. In addition, lower lignin contents make the fiber stronger and harder to break (Tran, 2006; Daud *et al*., 2014; Tutuş *et al*., 2015)

The fiber length, fiber width, lumen diameter, and cell wall thickness of okra stalks were measured as 0.64 mm, 16.97 µm, 9.64 µm, and 3.66 µm, respectively. The fiber parameters of okra stalks are presented in Table 3.

Felting ratio is calculated as the ratio of fiber length to fiber width. If this ratio is higher than 70, the tear, tensile, and double-folding strengths of the paper

Table 3 Fiber parameters of okra stalks in comparison with wood and other non-wood lignocellulosic materials
Tablica 3. Svojstva vlakana od stabljika bamije u usporedbi s vlakancima drva i ostalih nedrvnih lignoceluloznih materijala

Fiber dimensions *Dimenzije vlakana*	**Okra stalks** *Stabljike bamije*	**Wheat stalks** *Slama žitarica*	**Cotton stalks** *Stabljike pamuka*	**Rice stalks** *Rižina slama*	**Hardwoods** *Tvrdo drvo*	**Softwoods** Meko drvo
Felting ratio /*vitkost*	37.7	62	33	58	45-65	60-80
Elasticity /*elastičnost*	56.8	27	63	71	35-65	70-80
Rigidity /*krutost*	21.6	36	18	15	15-35	15-20
Runkel ratio / *Runkelov omjer*	0.76	2.7	0.6	0.4	0.5-2	0.3-0.5
Literature / *Literatura*	Current study *ovo istraživanje*	Tutuş and Çiçekler, 2016	Tutuş *et al*., 2010	Tutuş *et al*., 2004	Kirci, 2006	Kirci, 2006

will be high (Bektas *et al*., 1999; Kirci, 2006; Istek *et al*., 2009). The felting ratio of okra stalks fibers was calculated as 37.7 on average. This ratio shows that okra stalk fibers are more similar to hardwood fibers than softwood. Fibers with a coefficient of elasticity ratio between 50 and 75 are partly thick-walled. It is stated that these values are obtained from lignocellulosic materials with a density of 0.5–0.7 g/cm^3 (Bektas *et al.*, 1999). Since these fibers are partially crushed during papermaking, quality papers can be produced (Bektas *et al*., 1999; Ozdemir *et al*., 2015). The rigidity coefficient is between 15-35 for softwoods and hardwoods. When this value is high, the strength properties of the paper such as tensile, burst, and tear strengths are adversely affected (Bektas *et al*., 1999). In this study, the rigidity coefficient of okra stalk fibers was calculated as 21.6, which is within the acceptable limit for paper production. The Runkel ratio of okra stalk fibers is 0.76, and fibers with a Runkel index less than 1 are thin-walled and very suitable for paper production (Bektas *et al*., 1999; Ozdemir *et al.,* 2015). Based on the results of the analyzed chemical components and fiber morphological properties of okra stalks, it was concluded that okra stalk is suitable for pulp and paper production.

3.2 Chemical, physical and optical properties of okra stalk pulps
3.2. Kemijska, fizička i optička svojstva pulpe od stabljika bamije

The pulp yields and some chemical properties of the okra stalk pulps obtained by different cooking experiments are given in Table 4. The total yield of pulp produced from okra stalks was around 32-35 %. It was found to be lower than that of wheat stalk (50-55 %), cotton stalk (37-44 %) and rice stalk (41-56 %) pulps, which we have published in our previous works (Tutuş and Çiçekler, 2016; Tutuş *et al.,* 2004; Tutuş *et al.,* 2010). It is thought that the reason why the yields of pulp produced from okra stalks are lower than those of other stalks is due to the excess of substances dissolved in cold water and hot water, the lower cellulose content than other stalks, and the higher amount of material soluble in 1 % NaOH.

Kappa numbers of the okra stalk pulps show similar characteristics as stated in previous studies (Jahan *et al*., 2012), and similar to other species such as wheat, cotton, and rice stalks (Tutuş and Çiçekler, 2016; Tutuş *et al.,* 2004; Tutuş *et al.,* 2010). A low kappa number indicates that the lignin content of the pulp is low and is easier to bleach (Correia *et al.,* 2018; Przybysz Buzała *et al*., 2019; Birinci *et al*., 2020). Since okra stalk pulps have low kappa numbers (ranging from 25 to 33), they are easy to bleach, but considering the viscosity and DP values presented in Table 4, the strength properties of the papers produced after pulp bleaching will be low, since the chemicals used during bleaching will also damage carbohydrates.

It was observed that there was a certain increase in both pulp yield and viscosity values as a result of the addition of $NaBH_4$ to the cooking liquor. $NaBH_4$ has an effect on the yield as it has the capability of stopping the peeling reactions occurring in the cellulose chains. Although $NaBH_4$ decreased the kappa numbers at certain rates, it also increased the viscosity values. In recent studies, it has been observed that the kappa numbers of the pulps obtained by adding the $NaBH_4$ chemical to the cooking liquor in certain proportions decrease (Copur and Tozluoglu, 2008; Gülsoy and Eroglu, 2011; Istek and Gonteki, 2009).

Some physical and optical properties of the papers produced from okra pulps are given in Table 5.

The tensile index, burst index and brightness of the okra pulps were found as 60.7 (N·m/g), 3.00 kPa·m^2/g and 27.5 ISO%. The physical and optical properties were determined similarly as in previous studies dealing with okra stalk pulp, as indicated in Ta-

Table 4 Pulp yields and some chemical properties of okra stalk pulps
Tablica 4. Prinos vlakana i neka kemijska svojstva pulpe od stabljika bamije

Cooking No *Kuhanje*	**$NaBH_4$ charge** *Udio $NaBH_4$,* %	**Screened yield** *Prinos, nakon prosijavanja,* %	**Screen reject** *Odbačeno na situ,* %	**Total yield** *Ukupan prinos,* %	**Kappa No** *Kappa broj*	**Viscosity** *Viskozitet,* cm^3/g	**DP**
1	0	31.81^c	0.56^b	32.37^c	33^c	611^c	871^c
2	0.3	32.22^b	0.59^c	32.81^c	32^c	690^a	997^a
3	0.5	34.24^{ab}	0.54^{ab}	34.78^b	29^b	681^{ab}	983^b
4	0.7	34.43^a	0.46^a	34.89^a	25^a	673^b	970^b
Sig.	-	.002	.003	.015	.010	.012	.002
Jahan *et al.,* 2012	Soda-AQ	30.4-32.2	5.5-7.1	37.5-37.7	28-30	-	-
Jahan *et al.,* 2012	Kraft	37.6-39.0	0.8-6.4	38.4-45.4	22-41	-	-
Atik, 2002	Soda-AQ	-	-	45.0-47.3	82-86	-	-

*DP refers to degree of polymerization. Mean values with the same lower-case letters are not significantly different at 95 % confidence level according to Duncan's mean separation test.
**DP se odnosi na stupanj polimerizacije. Srednje vrijednosti s jednakim slovom prema Duncanovu se testu značajno ne razlikuju za razinu pouzdanosti od 95 %.*

Table 5 Physical and optical properties of papers produced from okra pulp
Tablica 5. Fizička i optička svojstva papira izrađenih od pulpe proizvedene od bamije

Cooking No *Kuhanje*	**$NaBH_4$ charge** *Udio $NaBH_4$,* %	**Tensile index** *Vlačni indeks,* N·m/g	**Burst index** *Indeks probijanja,* kPa·m²/g	**Brightness** *Svjetlina* ISO, %
1	0	60.7[c]	3.00[c]	27.5[d]
2	0.3	61.7[b]	3.11[b]	28.3[c]
3	0.5	62.6[ab]	3.26[ab]	28.9[b]
4	0.7	62.8[a]	3.33[a]	29.4[a]
Sig.	-	.003	.000	.000
Jahan *et al.*, 2012	Soda-AQ	39.6-71.4	2.3-4.3	-
Jahan *et al.*, 2012	Kraft	51.3-80.7	3.5-5.3	-
Atik, 2002	Soda-AQ	70-72	1.76-2.85	11.22-12.84

*Mean values with the same lower-case letters are not significantly different at 95 % confidence level according to Duncan's mean separation test. / *Srednje vrijednosti s jednakim slovom prema Duncanovu se testu značajno ne razlikuju za razinu pouzdanosti od 95 %.*

ble 5. It was reported that respective values for wheat stalks were determined as 60.6 (N·m/g), 3.10 kPa·m²/g and 34.8 ISO% (Tutuş and Çiçekler, 2016). In another study, where pulp was produced from cotton stalks, the breaking length and burst index were found to be 4.30 km and 2.60 kPa.m²/g, respectively (Jahan *et al*., 2004). The physical properties of pulp produced from okra stalks are generally similar to other annual plant stalks. Although the brightness value of okra stalks is low, the pulps can be increased to higher brightness values because they are easy to bleach.

It was observed that the physical and optical properties of the papers produced from okra pulp improved with the increase in the $NaBH_4$ charge. Namely, with the addition of 0.7 % $NaBH_4$ to the cooking solution, the brightness increased by about 7 %. In their study Gülsoy *et al*. (2016) conducted kraft pulping from maritime pine wood with the addition of KBH_4, which is a powerful reducing agent similarly as $NaBH_4$. They stated that the optical properties of the obtained papers increased in parallel with the increase in the KBH_4 charge.

In many studies, it has been reported that boron compounds prevent the peeling reaction during cooking and cause less damage to carbohydrates, and therefore, the physical and optical properties of the produced papers improve (Akgül and Temiz, 2006; Istek and Özkan, 2008; Istek and Gonteki, 2009; Gumuskaya *et al*., 2011; Erisir *et al*., 2015; Gülsoy *et al*., 2016).

4 CONCLUSIONS
4. ZAKLJUČAK

In this study, pulp and paper production from okra stalks and the characterization of pulp properties were made. According to the obtained results, the kappa numbers of the pulp produced from okra stalks were low and the viscosity values were high. It was noticed that the pulp yield was slightly lower than found in literature for other non-wood stalks. However, chemical properties show that okra stalk can be used as an alternative raw material for the pulp and paper industry. The physical properties of paper produced from okra stalk pulp are similar to those produced from wheat stalk and cotton stalk. The brightness values of the pulp of okra stalk were lower than literature values of the other non-wood stalks. However, due to the low kappa numbers, it is easily possible to obtain high-brightness pulps by bleaching. By adding 0.7 % $NaBH_4$ to the cooking liquor, the chemical, physical and optical properties of okra stalk pulps were improved. Based on the results of the analyzed properties, okra stalk pulps may be used to make a variety of papers by blending them with long fibers in certain proportions. Furthermore, by adding okra stalk fibers, the losses in the strength characteristics of the paper manufactured in waste paper recycling may be minimized. Similarly, the potential for using okra stalk fibers in the production of other papers is quite high.

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