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Biometry Features in Three Types of Rice Residues

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Abstract: In this research, fiber dimension and biometry properties were studied in three types of rice residues, which have been planted in the north part of Iran. Three types of rice stem residues such as Hashemi, Amrollah and Neda to determine fiber dimension (fiber length, fiber width, cell wall thickness and lumen diameter) and biometry features (slenderness, flexibility, Runkel and rigidity ratios) were selected. Analysis of variance (ANOVA) indicated that the types of rice residues had effect significant on fiber dimension, while the effect of this factor on the biometry properties weren't significant. Hashemi rice residues showed the greatest average fiber length. The lowest of fiber length and fiber lumen diameter values were found in Neda rice residues, while the values of fiber width and cell wall thickness in Amorllahi rice is lower than other rice residues. In general, results based on biometrical analysis indicated that Iranian rice residues fibers aren't promising fibrous raw material for the paper production.

Keywords: Rice residues · Fiber dimension · Biometry properties

INTRODUCTION

There is a growing interest in using agricultural residues such as rice straw for pulping and paper-making. As future worldwide fiber shortages are predicted, agricultural fibers are believed to be a potential substitution for wood fibers in certain paper applications. Rice straw as an agricultural residue has been used in pulp and paper production for a long time and remains one of the major raw materials in many countries. Several processes have been developed, yet all based on chemicalpulping technology [1].

Rice *(Oryza sativa)* is farmed annually in large surface of Iranian northern lands and as a consquence a large amount of straw is obtained. The objective of this work was to characterize the fiber biometry properties of three types of rice residues (Amrollahi, Hashemi and Neda), with the aim of generating information to facilitate the incorporation of residues material in industrial processes.

MATERIALS AND METHODS

Three types of rice residues (Hashemi, Amorllahi and Neda) were selected from the north of Iran. Rice plant residues remaining after harvests were used. The material was macerated using the Franklin method [2]. The pieces of fiber were cut with a scalpel and placed in test tubes in a solution of 1:1 acetic acid and oxygenated water of 30 volumes. The samples were dried in a stove at 60 ºC for approximately 1 week. The disaggregated particles were washed in water, stained with aqueous safranin at 1% for 3 min, dehydrated with alcohol at 96% and xylol. Subsequently, the fibers were dried, placed on slides and fixed with Canada balsam. Sixty six fibers were selected from three types of rice residues to determine fiber dimension (fiber length, fiber width, cell wall thickness and lumen diameter), which used from leica Image Analyzer System. Morphological properties were determined with these formulas:

Slenderness ratio = fiber length / fiber width
Flexibility ratio = lumen diameter / fiber width × 100
Runkel coefficient = 2 × cell wall thickness / lumen diameter
Rigidity coefficient = cell wall thickness / fiber diameter × 100

A variance analysis was made to establish the influence types of rice residues on fiber dimension and biometry properties and the differences were quantified through the Duncan test ($p \leq 0.05$).

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RESULTS AND DISSCUSION

Fiber Length: The length and width of fiber have an effect on the bulk, burst, tear, fold and tensile strength of paper. For pulp and paper production, species with higher lengths are preferred since a better fiber length net is achieved, resulting in a higher resistance of the paper. The analysis of variance results (ANOVA) indicated that the types of rice residues had significant effect on fiber length (Table 1). The highest and lowest of fiber length values were found in Hashemi (0.989 mm) and Neda (0.743 mm), respectively (Figure 1 and 2). The Duncan's mean separation test shows that there is a significant difference in the fiber length between Hashemi and Amrollahi and between Hashemi and Neda rice residues. The average of fiber length in rice residues (0.843 mm) is lower than that of Bagasses (1.59 mm) [3], Canola (1.17 mm) [4], Tobacco (1.07 mm) [5], Bamboo (2.30 mm) [6], Corn (1.52 mm) [7], Sunflower (1.28 mm) [5], Cotton (1.32 mm) [5], wheat (0.851 mm) [7], Kenaf stalks (2.60 mm) [8] and softwood fibers (2.7-4.6 mm) [9] and close to minimum value of hardwood fibers (0.7 -1.6 mm) [9].

Fiber Width: The analysis of variance results (ANOVA) indicated that the types of rice residues had significant effect on fiber width (Table 2). The highest and lowest of fiber width values were found in Hashemi (11.99 µm) and Amrollahi (9.45 µm), respectively (Figure 3). The Duncan's mean separation test shows that there is a significant difference in the fiber width between Hashemi and Amrollahi and between Hashemi and Neda rice residues. The average of fiber width in rice residues (10.30 µm) is lower than that of Bagasses (20.96 µm) [3], Canola (23.02 µm) [4], Tobacco (26.8 µm) [5], Bamboo (15.1 µm) [6], Sunflower (22.1 µm) [5], Cotton (29.3 µm) [5], Kenaf stalks (20 µm) [8], softwood fibers (32-43 µm) [9] and hardwood fibers (20-40 µm) [9] and is higher than that of Corn (8.4 µm) [7] and wheat (9.9 µm) [7].

Lumen Diameter: The analysis of variance results (ANOVA) indicated that the types of rice residues had significant effect on lumen diameter (Table 3). The highest and lowest of lumen diameter values were found in Hashemi (5.26 µm) and Neda (4.04 µm), respectively (Figure 4). The Duncan's mean separation test shows that there is a significant difference in the lumen diameter between Hashemi and Amrollahi and between Hashemi and Neda rice residues. The average of lumen diameter in rice residues (4.56 µm) is lower than that of Bagasses (9.72 µm) [3], Canola (12.50 µm) [5], Tobacco (16.3 µm) [5], Bamboo (6.9 µm) [6], Sunflower (15.6 µm) [5], Cotton (23 µm) [5] and wheat (6.8 µm) [7] and is higher than that of Corn (4.4 µm) [7].

Single Cell Wall Thickness: Decrease in cell wall thickness has an important effect of physical resistance of paper. The analysis of variance results (ANOVA) indicated that the types of rice residues had significant effect on cell wall thickness (Table 4). The highest and lowest of cell wall thickness values were found in Hashemi (3.36 µm) and Amrollahi (2.44 µm), respectively (Figure 5). The Duncan's mean separation test shows that there is a significant difference in the cell wall thickness between Hashemi and Amrollahi and between Hashemi and Neda rice residues. The average of cell wall thickness in rice residues (2.86 µm) is lower than that of Bagasses (5.63 µm) [3], Canola (5.26 µm) [4], Tobacco (5.3 µm) [5], Bamboo (4.17 µm) [6], Sunflower (3.3 µm) [5], Cotton (3.6 µm) [5] and is higher than that of Corn (2 µm) [7] and wheat (1.6 µm) [7].

Slenderness Coefficient: The analysis of variance results (ANOVA) indicated that the types of rice residues hadn't significant effect on slenderness coefficient (Table 5). The highest and lowest of slenderness coefficient values were found in Amrollehi (98.88) and Neda (83.55), respectively (Figure 6). The average of slenderness coefficient in rice residues (88.95) is lower than that of Bamboo (152.31) [6], Corn (180.95) [7] and Kenaf stalks (130) [8] and is higher than that of Bagasses (75.85 µm) [3], Canola (50.82) [4], Tobacco (39.92) [5], Sunflower (57.91) [5], wheat (85.95) [7] and Cotton (45.05) [5].

Slenderness power is an important factor having positive effect on strength, tear and burst strength according to physical test results of the paper. Generally, the acceptable value for this power of papermaking fibers are more than 33 [10] which these characteristics were found in three types of rice residues (Hashemi, Amrollahi and Neda).

Flexibility Coefficient: The analysis of variance results (ANOVA) indicated that the types of rice residues hadn't significant effect on flexibility coefficient (Table 6). The highest and lowest of flexibility coefficient values were found in Amrollehi (47.79%) and Neda (41.11%), respectively (Figure 7). The average of flexibility coefficient in rice residues (44.58%) is lower than that of Bamboo (45.69%) [6], Corn (52.38%) [7], Bagasses

Table 1: Analysis of variance between types of rice residues and fiber length

Fiber length	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.692	2	0.346	16.397	0.000
Within Groups	1.329	63	0.021		
Total	2.021	65			

Table 2: Analysis of variance between types of rice residues and fiber width

Fiber width	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	82.412	2	41.206	6.504	0.003
Within Groups	399.122	63	6.335		
Total	481.534	65			

Table 3: Analysis of variance between types of rice residues and lumen diameter

Lumen diameter	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.938	2	8.469	4.100	0.021
Within Groups	130.146	63	2.066		
Total	147.085	65			

Table 4: Analysis of variance between types of rice residues and lumen diameter

Cell wal thickness	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.615	2	4.308	4.584	0.014
Within Groups	59.200	63	0.940		
Total	67.815	65			

Table 5: Analysis of variance between types of rice residues and slenderness ratio

Slenderness coefficient	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2898.124	2	1449.062	2.305	0.108
Within Groups	39600.652	63	628.582		
Total	42498.776	65			

Table 6: Analysis of variance between types of rice residues and flexibility ratio

Flexibility coefficient	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	551.000	2	275.500	2.264	0.112
Within Groups	7666.848	63	121.696		
Total	8217.848	65			

Table 7: Analysis of variance between types of rice residues and Runkel ratio

Runkel proportion	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.760	2	.880	2.746	0.072
Within Groups	20.184	63	.320		
Total	21.943	65			

Table 8: Analysis of variance between types of rice residues and rigidity ratio

Rigidity ratio	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	137.750	2	68.875	2.264	0.112
Within Groups	1916.712	63	30.424		
Total	2054.462	65			

Fig. 1: Fibers in Hashemi (a), Amrollahi (b) and Neda (c) rice residues

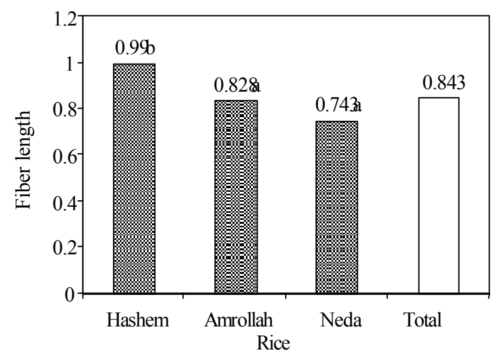

Fig. 2: The fiber length values in three different rice residues

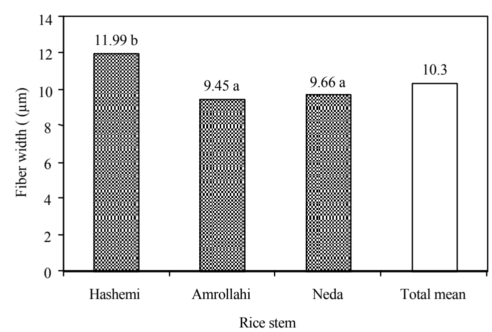

Fig. 3: The fiber width in three different rice residues

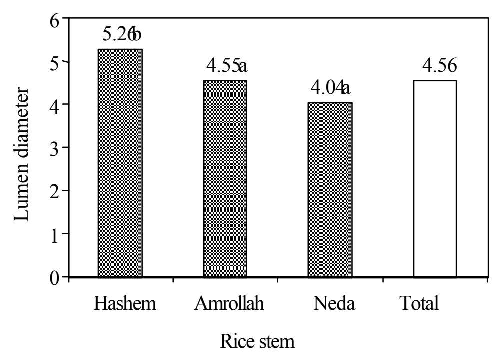

Fig. 4: The lumen diameter in three different rice residues

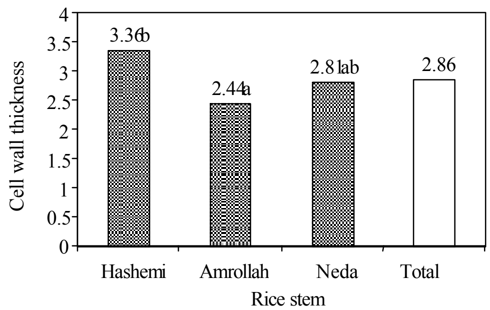

Fig. 5: The lumen diameter in three different rice residues

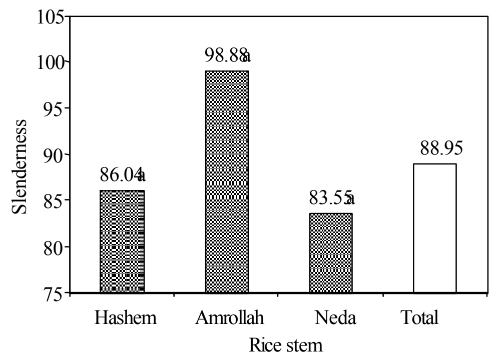

Fig. 6: The slenderness coefficient in three different rice residues

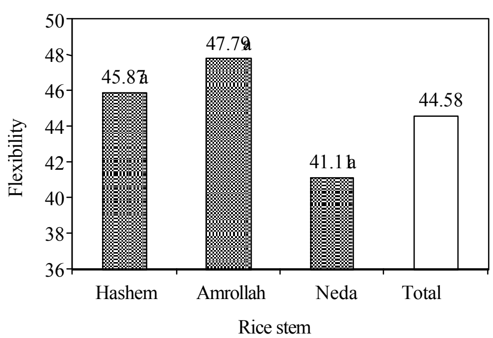

Fig. 7: The flexibility ratio in three different rice residues

(46.37%) [3], Canola (54.30%) [4], Tobacco (60.82%) [5], Sunflower (70.68%) [5], Wheat (68.68%) [7] and Cotton (78.49%) [5].

According to the flexibility ratio, there are 4 groups of fibers [11]: 1- high elastic fibers having elasticity coefficient greater than 75. 2- Elastic fibers having elasticity ratio between 50-75. 3- Rigid fibers having elasticity ratio between 30-50. 4- High rigid fibers having elasticity ratio less than 30. According to this, flexibility coefficient in Hashemi, Amorllahi and Neda rice residues were considered as rigid fibers. Rigid fibers don't have efficient elasticity, they aren't suitable for paper production and they are used more on fiber plate rigid carboard and cardboard production.

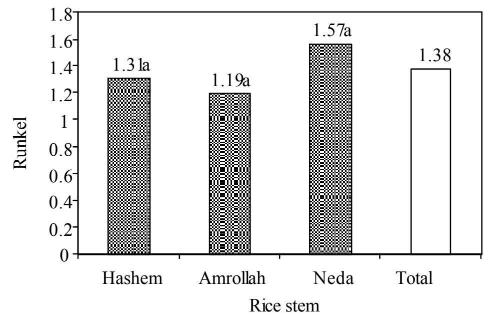

Fig. 8: The Runkel ratio in three different rice residues

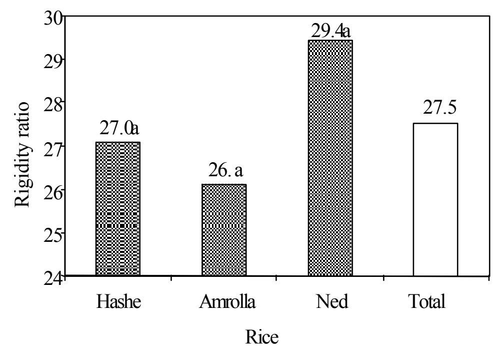

Fig. 9: The rigidity ratio in three different rice residues

Runkel Proportion: The analysis of variance results (ANOVA) indicated that the types of rice residues hadn't significant effect on Runkel coefficient (Table 7). The highest and lowest of Runkel coefficient values were found in Neda (1.57) and Amrollehi (1.19), respectively (Figure 8). The average of Runkel coefficient in rice residues (1.38) is higher than that of Wheat (0.47) [7], Bamboo (1.20) [6], Corn (0.90) [7], Bagasses (1.15) [3], Canola (0.84%) [4], Tobacco (0.65) [5], Sunflower (0.42) [5] and Cotton (0.31) [5].

Standard value of Runkel ratio is 1. Favorable pulp strength properties are usually obtained when value of Runkel ratio is below the standard value. In general, high Runkel ratio fibers are stiffer, less flexible and form bulkier paper of lower bonded area than low Runkel ratio fibers. This effect is related to the degree of fiber collapse during paper drying, a phenomenon affected by the cell wall thickness and degree of refining that fibers undergo prior to papermaking [12]. From this point of view, the rice different fibers aren't suitable for papermaking.

Rigidity Ratio: The analysis of variance results (ANOVA) indicated that the types of rice residues hadn't significant effect on rigidity coefficient (Table 8). The highest and lowest of rigidity coefficient values were found in Neda (29.44%) and Amrollehi (26.10%), respectively (Figure 9).

The average of rigidity coefficient in rice residues (27.52%) is higher than that of Wheat (16.16%) [7], Corn (23.80%) [7], Bagasses (26.86%) [3], Canola (22.84%) [4], Tobacco (19.77%) [5], Sunflower (14.93%) [5] and Cotton (12.38%) [5] and is a little lower than that of Bamboo (27.61%) [5]. High of this rate effects tensile, tear, burst and double fold resistance of paper negatively [13].

CONCLUSION

This work focused on the main biometry properties of rice residues in the north of Iran (Mazandaran province). The following conclusions could be drawn from the results of the present study:

- The analysis of variance showed that the types of rice residues had significant effect on fiber length, fiber width, thickness cell wall and lumen diameter, while the effect of this factor weren't significant on the biometry properties.
- The highest of fiber dimension was found in Hashemi rice residues.
- Lowest of fiber length and fiber lumen diameter values were found in Neda rice residues, while the values of fiber width and cell wall thickness in Amorllahi rice is lower than other rice residues.
- In total, the rice residues isn't suitable for paper productions due to low fiber length and low biometry features, z

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