Investigation on Wastage Analysis of Jute Fiber Spinning Using JBO and Soybean Oil Based Emulsion

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Abstract

Jute is golden fiber and major cash crop of Bangladesh. A great quantity of jute fibers is being produced and processed due to its availability. During jute fiber processing, mainly spinning, generation of different wastes creates a considerable amount of economic loss. This present study investigates the comparative analysis of generation of three major wastes namely, caddis, floating dust and sliver or thread waste during each operation of fiber processing with application of 18% (on the weight of jute reeds) mineral jute batching oil (JBO) based emulsion and vegetable source dhydrocarbon free bio-degradable soybean oil (SBO) based emulsion with same recipe for producing 16/1 lb/sp yarn.The results revealed that overall amount of wastages from spreading to precision winding was 3.36% higher in case of SBO based emulsion treatment than JBO. The amount of caddis and floating dust were 2.50% and 2.32% higher respectively where as sliver waste was 1.46% lower in case of SBO emulsified fiber than JBO one.

Keywords— Jute spinning, JBO, soybean oil, emulsion, caddis, sliver waste, floating dust.

1. Introduction

Jute is a coarser multicellular bast fiber that is mostly produced after cotton as natural fiber. Jute and jute products account for around 3% of overall export revenue in the country. Therefore, the jute industry's contribution to the advancement of agriculture and the socioeconomic status of this nation is crucial. The export of raw jute and jute products has earned 1,048.21 million US dollars [1]. *Corchorus* plant stems yield jute fiber. About thirty different species can be found all over the tropical regions under the umbrella of the genus *Corchorus*, which belongs to the family *Tiliaceae*. The commercial jute fiber is mainly obtained from two kinds of jute plants namely *Corchorus capsularis* and *Corchorus olitorius* [2]. Physically jute consists of bundles of fibers held together by a hard coating substance. The individual fiber is made of a large number of ultimate fibers cemented together by substances which have no regular shape (Figure 1).These ultimate fibers are again made of fibrils which are composed of molecular chains held together closely known as micelles [3]. The main physical properties of jute fiber are shown on Table1.

Table 1: The main properties of jute fiber [4]

Ultimate's	
– Length	2.5mm
– Diameter	18 microns
Single fibers	
– Length	0.2-30 in.
– Linear Density (Tex)	1·9-2·2
– Tenacity	40-70 g/tex
– Extension at Break	2·0 per cent
Moisture regain at 65% R.H.	
– Absorption	12·8 per cent
– Desorption	14·6 per cent
Specific gravity	1·48

The fibers taper towards each end and overlap one another. Thus, they produce a very compact and compound structure. The fiber bundles branch and re-unite from higher to lower levels in the stem producing matrix or mesh work. The mesh work produced by the compound bundles can be detected particularly near the root end. The existence of this mesh work provides difficulties in processing as the meshes have to be broken down in carding, re-arranged in drawing, regularized by doubling and united and twisted in spinning. This complex structure places limitations on the manufacturing properties of Jute fibers.

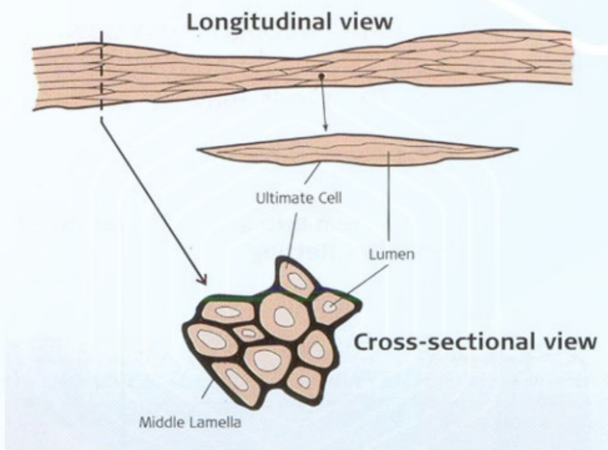

Figure 1: Micro structure of jute fiber [5]

Jute fiber is basically a compound of carbon. Chemically, it is totally a complex of organic molecules, which on ignition leave a little ash consisting of calcium, magnesium, aluminium, iron, etc. that are present either in the free state or bonded with functional groups of cellulosic chain.Typical chemical composition of jute fiber is shown in table 2.

Table 2: Chemical composition of jute fiber[6]

Name	Amount (%)
Cellulose	64.4
Hemicellulose	12
Lignin	11.8
Pectin	0.2
Wax	0.5
Water Soluble	1.1
Water	10

Alpha cellulose is the major constituent of jute. It forms the skeletal structure of jute fiber and belongs to the family of the compounds of carbohydrates (Figure 2).

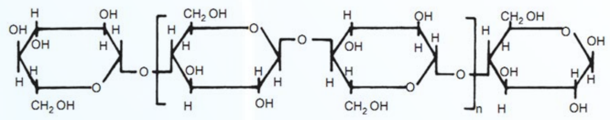

Figure 2: Structure of cellulose.

The hemicellulose in jute is a complex mixture of polysaccharides and polyuronides. It is formed by a number of comparatively low molecular weight polysaccharides of various sugar units, namely xylan in the pentosan, galactan in the hexosan, araban, rhamnosan, mannose, etc. (Figure 3).

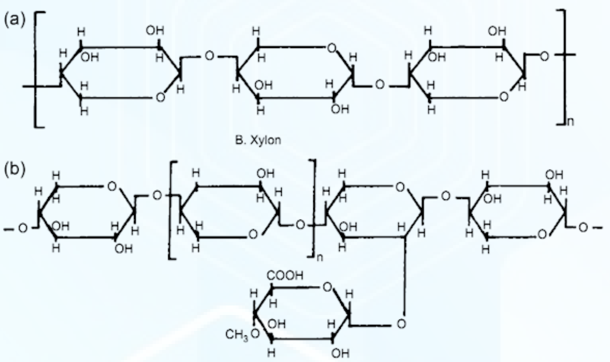

Figure 3: (a) Structure of Xylan (b) Structure of jute-hemicellulose

The lignin is the third major constituent of jute. Structurally, the molecule of lignin is a three-dimensional polymer of phenylpropane units consisting of phenolic hydroxyl group, methoxyl group, ether linkages and conjugated double bond in the alpha-position to the benzene ring (figure 4). There are evidences that there exists an ester linkage formed between the carboxyl group of hemicellulose (in uronic acid) and the hydroxyl group of lignin. Ether linkages between lignin and cellulose may be believed to exist. It is apparent that hemicellulose and cellulose are bonded by lignin and the three (alphacellulose, hemicellulose and lignin) are integrated.

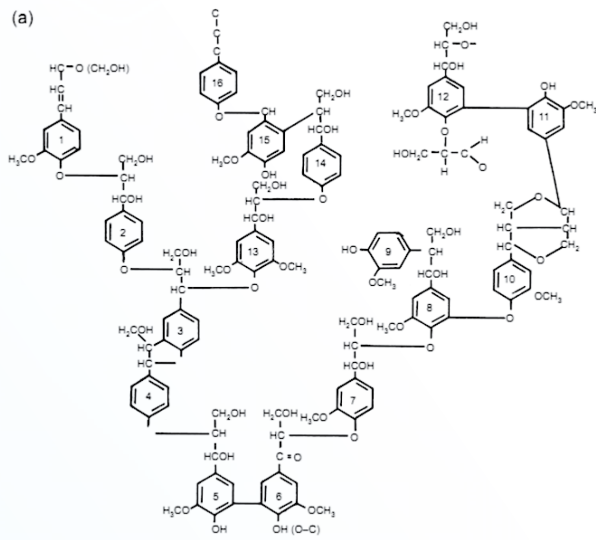

Figure 4: Schematic structure of jute-lignin

Jute fiber cannot be processed successfully in the dry condition due to excessive generation of short fibers. For this reason, an emulsion of oil-in-water is applied to jute to lubricate and soften it. The oil may be vegetable, or mineral. The water softens the fiber, improves its spinnability and prevents excessive fiber breakage during processing. The oil, residing on the fiber surface as a thin film, retards quick evaporation of water from the fiber body. Along with the oil, some jute mills are using different additives for ease of processing. After softener / spreader, the emulsified jute fiber bundles are kept under a cover for certain period of time. By this, a certain amount of heat is generated within the covered jute mass which along with moisture causes microbes to grow. Due to this microbial action on jute fibers, the fibers become softened. This stage is called 'Piling'.

During the processing of jute fiber, certain amount of wastes is created namely caddies, sliver wastage and floating dust. Caddies are un-spinnable short fibers, generally free from foreign particles. These are found from the beneath spreader, cards drawing frame and spinning framme passed through a dust shaker or waste cleaner. Sliver wastes are also soft wastes that are entanglement of slivers found during processing mainly due to operators' inefficiency and inefficient style change. Floating or invisible dust are seen surroundings of machine being floated during processing.

A great number of studies are found regarding utilization of jute waste for various perspective. Jabbaret al. investigated how a nanocellulose coating affected the thermomechanical and mechanical characteristics of jute/green epoxy composites. By purifying cellulose from jute fiber waste and converting it to nanocellulose by acid hydrolysis, composites were made by coating woven jute reinforcement with concentration of nanocellulose. The findings showed that, with the exception of tensile strength, the concentration of nanocellulose coating over jute reinforcement improved the composite parameters of tensile modulus, flexural strength, flexural modulus, fatigue life and fracture toughness [7]. Panaitescu et al. prepared polymer composite of neat polypropylene with jute fiber wastes and characterized the thermal and mechanical properties of it. Experimental results revealed that the reinforcing effect of waste fibers in polypropylene increased elastic modulus and tensile strength [8]. Siddiqua et al. studied the impact of oil and oil free emulsion on various properties of fiber and yarn. They concluded that excellent quality of yarn can be produced using glycerin without using oil and the use of rice bran oil with glycerin also yield better yarn properties than JBO. Basu et al. experimented three different vegetable oils (rice bran oil, palmolein oil and castor oil), a silicone emulsion, a mixed enzyme system and glycerin alone or in combination as conditioning agents as the sustainable substitute of JBO prior to mechanical processing for producing yarn. They suggested several efficient bio-friendly alternatives of oil in water emulsion to conventional JBO considering numerous improved yarn properties [9].

Jute is primarily used to make items for packaging of food grains. Through the distillation of crude oil in petroleum refineries, JBO is produced. Mineral based JBO is carcinogenic [10] because of its poly aromatic hydrocarbon (PAH) content (C^{12}–C^{31}). So, contamination of this oil from packing item to food item is a serious and concerning health issue. As a result, many buyers recommend using vegetable oil treatment in place of JBO and authority uses soybean oil (SBO) due to its availability and purity.

The aim of this current study is to analyze the generation of three above mention wastes considering the used of JBO and SBO based emulsion during fiber processing which may facilitate the factory owner can make economic decision easily.

2. Materials and methods

2.1 Materials and emulsion recipe

A batch of 60% hard and 40% soft jute was used in our study. Mineral JBO and edible quality soybean oil were used to prepare two oil in water (o/w) emulsion. JBO was procured from Meghna petroleum limited, Chittagong. Moisture content of JBO and SBO is approximately 0.4–0.5% and 0.08% respectively. A non-ionic emulsifying agent (Basica) was used for both emulsion preparation which was purchased from Shuncheer Enterprise Corporation, Taiwan. A 18% (on the weight of jute fiber) emulsion was applied on raw jute on spreader machine for approximately 2% oil content on final yarn (Table 3).

Table 3: Recipe for JBO based and SBO based emulsion

Recipe for JBO based emulsion		Recipe for SBO based emulsion	
Ingredients	Amount (%)	Ingredients	Amount (%)
Jute Batching Oil (JBO)	12%	Soybean Oil (SBO)	12%
Emulsifier	0.04%	Emulsifier	0.04%
Water	87.96%	Water	87.96%

2.2 Mechanical processing of jute fiber and winding

After preparing batch of 60% hard and 40% soft jute, morrahs (handful of jute reeds, approximately 1 kg) were fed on James Mackie & Sons made spreader machine. The output of this machine, roll, weighted 80kg and delivery sliver count was 55 lb/100 yards with a draft of 10. Above mentioned amount of emulsion, produced from automatic emulsion plant using above recipe was applied in this machine. The jute sliver was then conditioned for 48 hours on an average temperature of 40°C. At this stage, grown bacteria breaks some lignin bond that results opening of mesh structure of jute, facilitates for further carding operation. After piling, 8 rolls were fed on half circular down striking breaker card, which yields 21 pounds/100 yards sliver. The draft was 14 on this machine. Then 11 rolls of sliver rolls, produced from breaker card were fed on full circular double doffer up striking finisher card. The delivered sliver weight was 15lb/100yards with a draft of 10. Then sliver undergone three consecutive screw gill drawing frames with suitable delivery weight and draft, produced a sliver of 1 lb/100yards. Finally, 3rd drawn sliver was fed on apron draft sliver spinning frame of $4\frac{3}{4}$ inch pitch, 96 spindles and 3300 RPM which yields 16/1 lb/spindle yarn of 3.3 TPI. The spinning frame draft was 17 and flyer was bauxter type. Roll winding machine converts shorter package to bigger package and precision winding was done according to buyer requirements. The whole process was shown in figure 5.

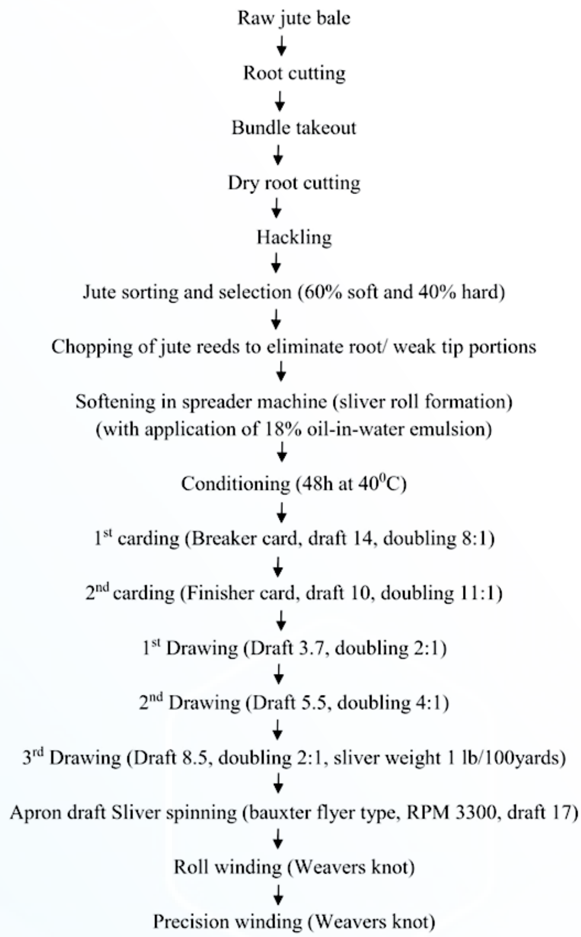

Figure 5: Mechanical processing for jute fiber processing (Spinning)

2.2.1 Standard Operating Procedure

i. All machines were cleaned properly, all caddies were removed.

ii. Total input was weighed using available scales.

iii. Moisture regain% of the input was taken using moisture meter in the presence of a representative from quality inspection department.

iv. All the sliver/thread wastage during processing were collected & stored in a sliver can.

v. Output weight of each doff was carefully taken using available scales.

vi. Output MR% was taken in the presence of a representative from quality inspection department

vii. Lastly, all the machines were cleaned, caddies were collected & weighed using appropriate scale.

viii. All the sliver/thread wastage accumulated in the sliver can were weighed.

ix. From the total wastage, all physical wastages found (e.g. Caddies & sliver wastage) were subtracted to get the amount of invisible wastage.

x. For spreader, emulsion application rate was calculated in the presence of a representative from quality inspection department.

3. Moisture adjustment

Amount of moisture has a significant effect on the properties of textile fiber. Jute fiber is a hygroscopic fiber. It has the ability to absorb moisture from a moist environment and release it to a dry environment. Relative humidity of surrounding air is very important here, as amount of moisture on fiber directly depends on it. As a result, the amount of moisture is to be considered during input and output of each operation. Moisture in fiber can be expressed in two ways, namely moisture content and moisture regain. Moisture content is the ratio of weight of moisture present on the fiber to total weight of sample while moisture regain is the ratio of weight of moisture present on the fiber to weight of bone-dry fiber, expressed as percentage. In this present study, moisture regain is used to indicate moisture percentage. Moisture regain of input and output materials was measured using moisture meter. Table 4 shows the amount of moisture for each processing. Loss due to moisture is adjusted every time of input and output processing [11].

4. Calculation of Wastage Percentage

Machine Name	Emulsion of JBO		Emulsion of Soybean oil	
	Input Moisture	Output Moisture	Input Moisture	Output Moisture
Spreader	18.4%	16.5%	18.7%	17.9%
Breaker Card	25.0%	22.5%	21.0%	19.6%
Finisher Card	28.0%	27.6%	21.8%	18.2%
1st Drawing	25.3%	23.6%	22.4%	19.9%
2nd Drawing	20.2%	19.6%	25.3%	23.1%
3rd Drawing	20.5%	19.7%	23.1%	20.3%
Spinning	22.0%	20.3%	20.5%	16.0%
Roll Winding	17.8%	17.1%	16.6%	15.7%
Precision Winding	18.8%	18.5%	14.6%	13.9%

Mainly amount of three types of wastage, namely, sliver/thread wastage, caddies and floating dust/invisible dust were calculated in this study during each operation. Feed weight, output weight, input and output moisture regain% and individual amount of waste were required to calculate each waste percentage. Necessary calculations were performed using following equations.

a. Total weight of wastage after adjusting for moisture

$$= \{\text{Total feed weight} - \text{Total feed weight} \times (\text{Input moisture\%} - \text{Output moisture \%})\} - \text{Total Output weight}$$

b. $$\text{Overall Wastage \%} = \frac{\text{Total weight of wastage after adjusting for moisture}}{\text{Total feed weight} - \text{Total feed weight} \times (\text{Input moisture\%} - \text{Output moisture\%})} \times 100\%$$

c. $$\text{Caddies \%} = \frac{\text{Weight of Caddies}}{\text{Total feed weight} - \text{Total feed weight} \times (\text{Input moisture\%} - \text{Output moisture\%})} \times 100\%$$

d. $$\text{Sliver or thread waste} = \frac{\text{Weight of Sliver or thread waste}}{\text{Total feed weight} - \text{Total feed weight} \times (\text{Input moisture\%} - \text{Output moisture\%})} \times 100\%$$

e. Weight of floating on invisible dust

$$= \text{Total weight of wastage after adjusting for moisture} - (\text{Weight of Caddies} + \text{Weight of Sliver or thread waste})$$

f $$\text{Floating dust \%} = \frac{\text{Weight of Floating dust}}{\text{Total feed weight} - \text{Total feed weight} \times (\text{Input moisture \%} - \text{Output moisture\%})} \times 100\%$$

5. Results and discussion

5.1 Caddis analysis

Amount of Caddis% during different fiber processing using JBO based emulsion and SBO based emulsion are shown in figure 7. It is clear from the figure that amount of generation of caddies on carding process is significant. Two carding operation causes 1.98% higher caddies on SBO emulsified processing over JBO and here Breaker card alone generates 1.56% higher caddies than JBO processing. Because breaker carding is the first process of jute carding for breaking down the messy structure of jute reeds to generate individual fibers and also mix the jute fibers of different quality. It generates a uniform and un-entangled assembly of fibers called sliver. As the cylinder, workers and stripper rotate their pins causes splitting and opening the jute fiber which is passing between them. Tin cylinder, workers and stripper can not control the fall out of short fiber if their amount is high.

a b c

Figure 6: Generation of caddis during (a) breaker carding (b) finisher carding (c) spinning

Overall caddis percentage is 2.5% higher in case SBO based emulsion application than JBO. The possible reason is that highly viscos and low lubricity of SBO emulsion of lower coefficient of friction causes higher fiber breakage, as a result fiber drop out increase and generation of waste becomes high. Again, esterification of fatty acid of soybean oil with hydroxyl group of lignin may occur, which may cause generation of short fiber due to lower intermolecular force on jute fibers in case of SBO emulsified fibers. Another reason may be the amount of moisture retention capability of JBO is higher, causes strong bonding in JBO processing.

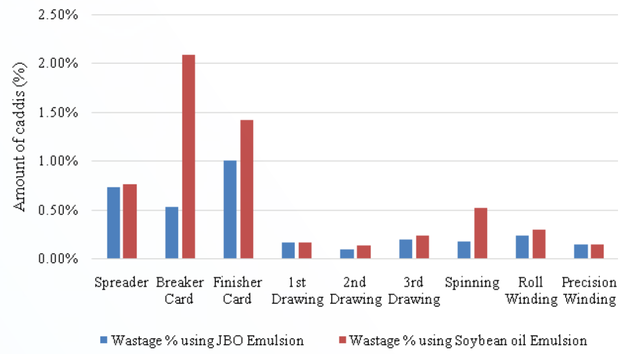

Figure 7: Generation of caddis during processing

5.2 Invisible/Floating dust analysis

Floating dust are invisible like waste that are created due to the breakage of short fiber during processing. Breaker carding (0.96% higher) and sliver spinning (1.18% higher) creates a significant amount of floating dust while using SBO based emulsion than JBO (Figure 8 and 9).

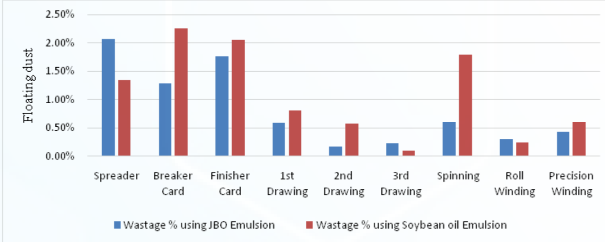

Figure 8: Generation of floating dust during each operation

Figure 9: Generation of floating dust during carding

5.3 Sliver/Thread wastage analysis

Sliver or thread wastage is not significantly related to the use of emulsion. The main reason for this was generation is due to change over related activities. Figure 10 and 11 shows the amount of sliver and thread waste for different processing. Other reasons for this type of wastage are unskilled workers, improper cleaning of machines, pinion change, pin breakage, machine jamming, less supervision, quality of jute and so on.

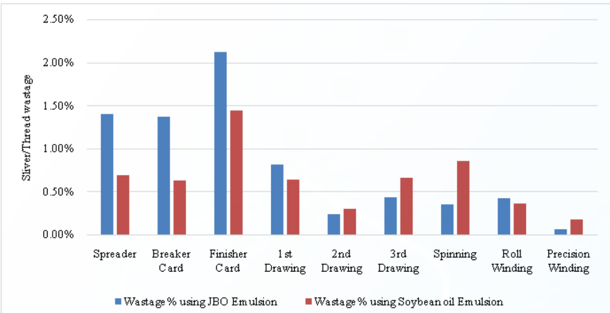

Figure 10: Generation of sliver or thread waste during eachoperation

a b

Figure 11: Generation of sliver waste (a) and thread waste (b)

5.4 Process- wise total wastage analysis

Figure 12 shows the process- wise or machine wise total amount of wastage, that means summation of caddis, sliver waste and floating dust. It is clear from the figure that, carding operation and spinning generates significant amount of wastages. Spinning and breaker card creates 2.03% and 1.76% higher waste in case of SBO emulsion than JBO one. Along with the reason mentioned above related to JBO and SBO based emulsion, fiber strength, improper twist and ends breakage are also responsible for spinning waste generation.

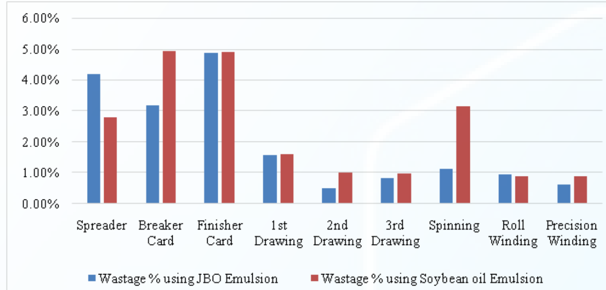

Figure 12: Process- wise total wastage

5.5 Category-wise wastage analysis

From figure 13, it is obvious that, the amount of caddis and floating dust were 2.50% and 2.32% higher respectively whereas sliver waste was 1.46% lower in case of SBO emulsified fiber than JBO one.

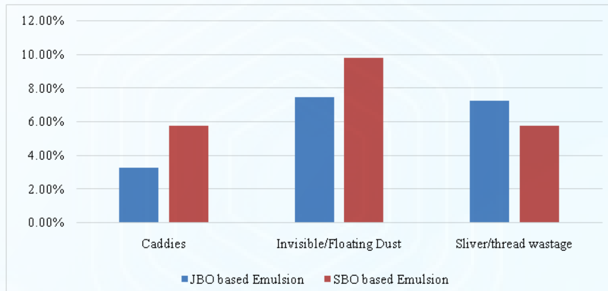

Figure13: Category wise total wastage

5.6 Overall wastage analysis

Figure 14 indicates that total amount of waste due to JBO based and SBO based emulsion were 17.90% and 21.26% respectively. The overall amount of wastages from spreading to precision winding was 3.36% higher in case of SBO based emulsion treatment than JBO.

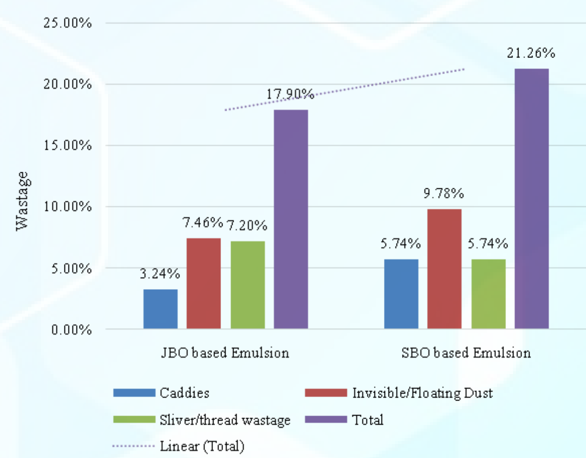

Figure 14: Overall wastage

6. Conclusion

According the requirement of buyer, detrimental carcinogenic hydrocarbon free oil, here bio-based vegetable oil named soybean oil was used as an ingredient of oil in water emulsion to assess the generation of waste with comparison with JBO based emulsion. Our study found a higher amount of wastage in case of SBO based emulsion compared with conventional mineral based JBO due to lower lubricity and lower moisture retention capability of soybean oil. Amount of wastes is not solely dependent on the use of oil in emulsion, but also other factors like machine condition, moisture or weather change, quality of jute, immature or over mature pilling, less twist per inch or high RPM, machine setting, efficiency of operator etc. play significant role, which may be the further interesting topics of research for the spinning personnel.

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Conflict of interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

Reference

[1] Bangladesh Economic Review 2022. Finance Division, Ministry of Finance, Government of the People's Republic of Bangladesh. [Online]. Available: https://mof.gov.bd

[2] R. R. Franck, Bast and other plant fibers, vol. 39. Crc Press, 2005.

[3] H. U. Ahmed, Jute Spinning (descriptive). Fatima Ahmed, 1967.

[4] R. R. Atkinson, Jute: Fiber to Yarn. Chemical Publishing Company, 1965.

[5] S. Roy, Ed., Jute basics, 1st ed. Dhaka: International Jute Study Group, 2010.

[6] N. Chand and M. Fahim, "Natural fibers and their composites," Tribology of Natural Fiber Polymer Composites, pp. 1–59, Jan. 2021, doi: 10.1016/B978-0-12-818983-2.00001-3.

[7] A. Jabbar, "Extraction of Nanocellulose from Waste Jute Fibers and Characterization of Mechanical and Dynamic Mechanical Behavior of Nanocellulose-Coated Jute/Green Epoxy Composites BT - Sustainable Jute-Based Composite Materials: Mechanical and Thermomechanical Beh," A. Jabbar, Ed. Cham: Springer International Publishing, 2017, pp. 71–85. doi: 10.1007/978-3-319-65457-7_5.

[8] D. M. Panaitescu, M. D. Iorga, S. SERBAN and A. N. Frone, "Composite materials of polypropylene and waste jute fibers," Materiale Plastice, vol. 47, no. 1, p. 1, 2010.

[9] G. Basu, S. S. De and A. K. Samanta, "Effect of bio-friendly conditioning agents on jute fiber spinning," Ind Crops Prod, vol. 29, no. 2–3, pp. 281–288, Mar. 2009, doi: 10.1016/j.indcrop.2008.05.008.

[10] N. K. Mehrotra, S. Kumar and M. Antony, "Carcinogenic Property of JBO(P) Variety of Jute Batching Oil," Drug Chem Toxicol, vol. 11, no. 2, pp. 181–193, Jan. 1988, doi: 10.3109/01480548808998221.

[11] B. P. Saville, Physical testing of textiles. Elsevier, 1999.