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Physical and tactile properties of woven textile textures from plant and agro-waste materials

Lalita Rani and Kanwaljit Brar

Abstract
The present study was undertaken to address the issues of plant and agro-waste utilization to the benefit of mankind. The ultimate aim of plant and agro-waste management is to make the best utilization through useful product development on one hand and control the pollution on the other. Development of textile textures from plant and agro-waste may partially help in addressing to this problem, in addition to providing self-employment through entrepreneurship development in related products. The selected wheat and paddy straws and date palm leaves were examined for their physical parameters. The wheat straw at internode N3 showed highest thickness 0.48mm. The higher diameter of the N3 and N2 internode was observed (4.30mm and 3.34mm). The N1 had maximum length 33.4 cm. The higher diameter of paddy straw internode N3 (4.08mm) was observed compared to N4 internode (3.38mm). N1 showed maximum length (39.2 cm) followed by 22.54 cm, 15.12 cm and 8.8 cm length of N2, N3 and N4, respectively. Paddy straws N3 and N4 were used. The higher thickness of date palm RL4 and RL1 (0.30mm and 0.29mm) was observed compared to RL3 and RL2 (0.26mm and 0.19mm). The width of date palm leaves of RL1 and RL4 ranged between 0.17 cm-1.04 cm and 0.16 cm-1.08 cm, respectively. RL4 showed maximum length (30.40 cm) followed by 30.26 cm length of RL1 of date palm leaf. The weight (GSM) of PSP_1 (paddy straw × polyester), WSP_2 (wheat straw × polyester) and DPP_3 (date palm leaves straw × polyester) was 276.00 g/m^2, 199.90 g/m^2 and 186.00 g/m^2, respectively. Thus, woven texture PSP_1 had highest weight (276.00 g/m^2). Thickness of DPP_3 was minimum (0.990mm), while thickness of PSP_1 was highest (1.521mm). These woven textures were found suitable for various end-uses such as coaster plates, bags, purses, file cover, mats, small window curtains, baskets, containers and trays.

Keywords: Wheat and paddy straw, date palm leaves, physical parameters, woven textures

Introduction
Burning of agricultural residues in fields, particularly of rice, has become a major source of visible pollution. Considering the urgency to curtail the burning of rice straw to reduce environmental hazards, the state government has already brought out a notification in this regard. There are several options which are being practiced and/or being tried on some scale such as fuel for generation of power in brick kilns, production of bio-fuels, retention and incorporation in soil for improvement of soil health, use as feed stock, mushroom cultivation, biogas generation, etc. Still there are a number of unexplored opportunities to use this bio-resource. Looking at the overall environmental and agro-industrial-economic scenario, the state of Punjab targets to completely phase out its burning in open fields and utilize it for gainful purposes. In order to achieve the afore-mentioned objectives, the state government endeavours to accelerate comprehensive usage of rice straw targeting its utilization to the tune of 5.73 million tons in 2016-17 (Jain *et al* 2014) [4].

An established body of research is needed to analyze the barriers and challenges for entrepreneurs of better utilization of straws for future agribusiness opportunities. The majority of the progressive countries are very wealthy in agricultural fibres, but a large part of the agricultural waste is being used as energy. India has got a huge amount of total world production of rice pods, jute, stems, bagasses, groundnut shells and coconut fibres. All these non-conventional fibres have outstanding physical and mechanical properties and can be used more efficiently in the development of composite materials for different building applications (UNIDO 1975).

According to Statistical Abstract of Punjab (2012), estimated targets for 2016-17 include the utilizing paddy straw of 4.5 MT biomass to produce energy, reincorporation in soil of 1.1 MT, 0.03 MT for ethanol and 0.1 MT for other uses. Even then there would be balance of 9.27 MT of unutilized paddy straw. Thus, realizing the need of the time below mentioned straws and

leaves were selected to diversity their utilization in the natural form.

- To study the physical and tactile parameters of selected straws and leaves.
- To prepare textures from wheat and paddy straws and date palm leaves.

Methodology

Identification and Selection of Plant and Agro-waste Materials

Three types of raw materials, i.e. wheat straw, paddy straws and date palm leaves, suitable for use in natural form for texture development were selected. The visual and physical properties of three selected straws and leaves studied were thickness, diameter and length. Woven samples were developed by using polyester threads.

Procurement of Materials

Wheat and paddy straws were collected from the fields of Punjab, while date palm leaves were collected from roadside wild date palm plants. Paddy and wheat straws, and date palm leaves were considered suitable for developing textile textures in their natural form. The spun polyester yarns were procured from Ludhiana market.

Methods

Woven Samples of the Straws and Leaves

Three samples of straws and leaves were woven in plain weave using 100 per cent spun polyester (2/45 yarn count) yarn as warp.

Preparation of Raw Materials

The wheat and paddy straw were collected from the fields of Punjab after harvesting was done. The date palm leaves were collected from wild date palm plants or bushes growing on roadside. The upper part of the wheat and paddy straws was selected for weaving. The immature and dyed date palm leaves were selected for weaving. The selected straws and leaves were sun-dried and stored in ventilated room before weaving.

Dyeing of Date Palm Leaves

- Date palm leaves and *munj* grass were first cleaned with cold water properly and dried it before dyeing
- Then, the direct dyes, which were used for dyeing cotton yarns was mixed in the warm water and boiled for 30-40 minutes. After boiling the dye liquor, then cooled it for some time
- The raw materials were steeped into dye bath overnight so that leaves/grass was dyed properly
- Then the raw materials were washed in cold water to remove extra colour from the leaves and dried in shade These were tied properly and preserved for one season.

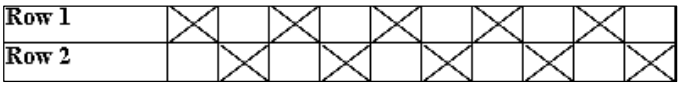
Preparation of Textures from Straws and Leaves

Thickness of the straws was examined before using them for weaving. Wheat straws were splitted lengthwise before weaving, but paddy straws were used in original form. Even date palm leaves were splitted into narrow stripes for weaving. All the samples were woven in plain weave using frame loom. Polyester yarns in different colours such as white, orange and green were used as warp yarns, and straws were used as weft.

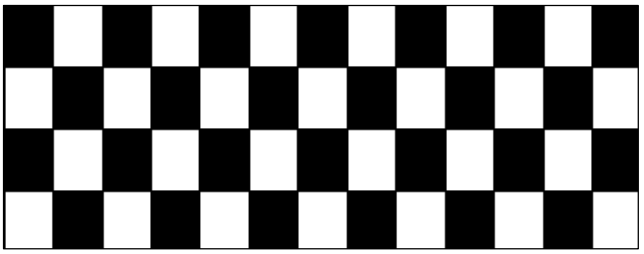
Threading and Lifting Plans

Woven samples were prepared by using plain weaves. The threading and lifting plans for twill weaves have been shown graphically below.

Samples in Plain Weave: Three woven samples from straws and leaves were prepared in plain weave using polyester yarn in same counts (2/65).



Threading plan of two harness loom for plain weave



1, 2, 1, 2, 1, 2 repeat from
Lifting plan of plain weave

Testing of Wheat and Paddy Straws and Date Palm Leaves and Prepared Woven Textures

The testing of physical properties of the wheat and paddy straws and date palm leaves-thickness, diameter, width and length was done at Physics Laboratory of Punjab Agricultural University, Ludhiana, using standard testing methods. The physical properties of woven textile textures-GSM and thickness were tested at North Indian Textile and Research Association (NITRA), Ghaziabad using standard testing methods.

Physical Properties of Prepared Textures from Straws and Leaves

The physical properties of woven textile textures- GSM and thickness were examined

Result and Discussion

Analysis of Physical Properties of Selected Raw Materials

The physical properties of wheat, paddy straws and date palm leaves were evaluated.

Wheat Straws (*Triticum Aesticum)*

Cultivated wheat plant is a seasonal crop of India in the genus *T. aesticum.* In India, wheat is harvested between mid-marches to April month. The maturity time of the crop differs from zone to zone. Wheat is a tall, seasonal plant with a height ranging from two to six feet in early varieties. The stem of wheat plant is erect, cylindrical, jointed (thick nodes) and smooth. Wheat straw is one of the most important agricultural residues. India is second largest producer of wheat in the world, with production hovering around 95.85 MT (Department of Agriculture of Punjab 2013-14). Joshi *et al* (2007) [5] reported that the better utilization of wheat by-products can also support the basket-making, cosmetics, soil fertility, bio charcoal, fuel, livestock bedding and fodder, medicine and fermentation industry. They can also be a source of an additional income for the farmers and management of wheat byproducts in textile industry.

Visual and Tactile Properties of the Wheat Straw

Visual and tactile properties relate to the way human senses such as touch and sight contribute to the perception of the materials. Luster results from the way light is reflected by a surface. Shiny or bright materials reflect a great amount of light (Wynne 1997) [14]. Wheat straws are lustrous and yellowish in colour. Wheat straws have smooth, shiny, slippery surface, round and hollow stems with thick nodes in contrast of the paddy straws (Fig 1a). Bending at 90° many times in same direction does not crack the straw, but it does develop a crease mark. Splitted of the straw into four parts occurs on bending. Being, hollow it flattened and splits into four parts longitudinally. When folded in opposite directions, it cracks and breaks. Thus, wheat straws behave differently depending on the angle and direction of bending. It can be easily wrapped around any cylindrical shape without breaking.

Evaluation of Physical Properties of the Wheat Straw at Different Internodal Positions

The data in Table 1 summarize physical properties such as thickness, diameter and length of different internodal position of straw.

Table 1: Physical properties of the wheat straws at different internodal positions

Parameters	Internodes of wheat straw			
	N1	N2	N3	N4
Mean thickness (mm)	0.25	0.31	0.48	0.38
Mean diameter (mm)	3.10	3.34	4.30	3.25
Mean length (cm)	33.4	19.78	15.96	11.4

*N1, N2, N3 and N4-first, second, third and fourth internode positions, respectively

It is clear from the data in Table 1 that the straw at internode N3 showed highest thickness 0.48mm followed by N4 straw internode (0.38mm). Mean thickness of N2 and N1 was 0.31 and 0.25mm, respectively. The diameter of the third and second internode (4.30 and 3.34mm) was more than N4 and N1 (3.25 and 3.10mm). The N1 had maximum length (33.4 cm) followed by N2 having length 19.78 cm. Length of N3 and N4 was 15.96 and 11.4 cm, respectively.

Paddy straw (*Oryza sativa)*

Paddy crop (*O. sativa*), grown in approximately 2.8 million hectare in Punjab, has established as major cereal crop alternating with wheat in the cropping pattern. The paddy crop is harvested between mid-Septembers to October in this state. A total of approximately 17 million tonnes of paddy straw is generated in the state which includes paddy straw from long stature basmati rice, short stature high yielding non-*basmati* varieties, etc. In Punjab alone about 20 million tonnes of paddy and wheat residues are being burned in situ annually (Singh *et al* 2005) [11].

Visual and Tactile Properties of the Paddy Straw

Visual and hand feel properties contribute substantially to the consumer's overall acceptance or preference of materials. Understanding the tactile feel of materials requires a valid and reliable sensory evaluation method. For over fifty years, research has attempted to use the sense of touch to measure the sensory properties that contribute to the 'hand', 'handle' or 'hand feel' properties (Kadolph 2006) [6]. Tactile and visual observations of surface roughness and smoothness, softness and hardness, colour and textures were conducted for paddy straws. The paddy straws are golden or zinc yellow and light brown shinny. It is flexible and easily bendable, on pressing it easily gets flattened. It does not split longitudinally on flattening or bending. It could be coiled and straitened again without the appearance of any crack, thus, it could be reshaped. If can easily be splitted longitudinally and make sound on breaking. Each of the internodes varies in colour due to change in climatic conditions and soils type used. The paddy straws have rough but soft surface and good bending strength. These straws can easily be woven with any kind of yarns (Fig 1b).

Evaluation of Physical Properties of the Paddy Straw at Different Internodes Position

The straw internodes were separated out according to their position from ear. The physical properties which were examined are thickness, diameter and length per internode position of paddy plant.

Internode thickness of *Pusa* basmati variety was measured. The maximum thickness was observed in case of N3 and N4 nodes 0.402mm and 0.318mm followed by 0.309mmand0.298mm thickness in case of N2 and N1, respectively. The higher diameter 4.08mm of internode N3 was observed compared to N4 internode (3.38mm), while the diameter of N2 and N1 was 3.06mm and 2.88mm, respectively.

Table 2: Physical properties of the paddy straw at different internode positions

Parameters	Internodes of paddy straw			
	N1	N2	N3	N4
Mean thickness (mm)	0.298	0.309	0.402	0.318
Mean diameter (mm)	2.88	3.06	4.08	3.38
Mean length (cm)	39.02	22.54	15.12	8.78

*N1, N2, N3 and N4-first, second, third and fourth internode positions, respectively

Esehaghbeygi *et al.* (2009) reported that taller plants have lower stem diameter and shearing energy will be decreased. The N1 showed maximum length (39.2cm) followed by 22.54 cm, 15.12 cm and 8.8 cm length of N2, N3 and N4, respectively. According to Bright and Kleis (1964) [7] and Persson (1984) [10] these properties depend on the species, variety, stalk diameter, maturity, moisture content and structure. Paddy straws N3 and N4 were used for creating textures.

Date Palm Leaves (*Phoenix sylvestris*)

The wild date palm (*P. sylvestris*) has been cultivated and prized from remotest antiquity. Hadrami (2014) [3] reported that over 100 million trees are currently grown worldwide on an estimated area of 1 million hectare. All parts of the date palm yield products of economic value. Its trunk furnishes timber; the midribs of the leaves supply materials for crates and furniture; the leaflets used for basketry; the leaf bases, for fuel; the fruit stalk, for rope and fuel; the fibres, for cordage, packing materials and composites; and the seeds are sometimes ground and used as stock feed. Date palm trees constitute a potentially large source of raw materials for manufacture of pulp and paper in form of leaves. The leaves comprise of mainly three parts, commonly known as frond bases, frond midrib and leaflets (Bukhaev and Sabarwal 1984) [1]. Date palm leaves are very developed and can reach several

square meters in area. The leaves are eract, arranged in a spiral pattern on the trunk. Sheathing becomes denser at the top of the tree forming a crown with hundreds of leaves forming a terminal rosette. The leaves are pinnate with needle-sharp tips to defend the plant from grazing animals and reduce water loss. Vegetative, floral or intermediate auxiliary buds can be found at the base of each leaf. During the juvenile life of the tree, these buds can form the so-called offshoots or suckers, which can developed into an adult palm and bear fruits at maturity. After harvesting the number of frond bases that are likely to get wasted are estimated at 210 million tons annually (Bukhaev and Sabarwal 1984) [1], and this can be made available for more useful purposes. If proper attention is given, they could be successfully used as a source for textiles.

Visual and Tactile Properties of the Date Palm Leaves

Hand is the way a textile feels to the skin. Hand is often described using adjectives such as warm or cool, bulky or thin, and slick or soft. Hand may be evaluated by feeling a material between the fingers and thumb. Both human assessment and instrument measurement are used to determine suitability for various end-uses (Kadolph 2006) [6]. The visual properties of the date palm leaves such as colour and texture were observed. The colour of the date palm leaves vary from light pale golden or light *khaki*. It is stronger than paddy and wheat straws (Fig 1c). It can be easily splitted longitudinally into very fine and narrow stripes which can be woven or shaped easily. It is flattened smooth and slippery in lengthwise direction. It is irregular in touch in crosswise direction.

Evaluation of Physical Properties of the Date Palm Leaves

The data pertaining to physical properties of date palm leaves have been presented in Table 3.

Table 3: Physical properties of the date palm leaves

Parameters	Date palm leaves			
	RL1	RL2	RL3	RL4
Mean thickness (mm)	0.29	0.19	0.26	0.30
Mean width (cm)	0.17-1.04	0.14-0.96	0.15-0.96	0.16-1.08
Mean length (cm)	30.26	28.18	28.44	30.40

*RL1, RL2, RL3 and RL4 are the rachis leaves of different plants.

The data presented in Table 3 revealed that higher thickness of RL4 and RL1 (0.30mm and 0.29mm) in contrast to RL3 and RL2 (0.26mm and 0.19mm). The width of the date palm leaves was measured in terms of minimum to maximum range. The width of date palm leaves of RL1 and RL4 were observed ranging between 0.17 cm-1.04 cm and 0.16 cm-1.08 cm as compared to RL3 and RL2, i.e. 0.15-0.96 and 0.14-0.96mm, respectively. RL4 showed maximum length (30.40 cm) followed by 30.26 cm length of RL1 of date palm leaf. Minimum length of RL3 and RL2 was 28.44 cm and 28.18 cm, respectively.

(a) Wheat straws

(b) Paddy straws

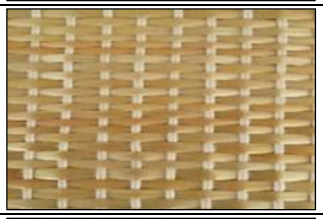
(c) Date palm leaves

(d) Spun polyester yarns

Details of Developed Woven Textile Textures

Total three woven samples were developed using 2/45 polyester yarns as warp for each of paddy and wheat straws and date palm leaves. Three woven samples were assigned code such as PSP_1, WSP_2 and DPP_3, respectively (Table 4)

Table 4: Codes assigned to developed woven textile textures from straws and leaves

Codes of woven developed textures	Composition of warp yarn	Composition/EPI and PPI used in weft yarn	Type of weave used	Images of woven samples
PSP_1	2/45 polyester	Paddy straw EPI=12, PPI=2	Plain weave	
WSP_2	2/45 polyester	Wheat straw EPI=9, PPI=5	Plain weave	
DPP_3	2/45 polyester	Date palm leaves EPI=40, PPI=7	Plain weave	

Analysis of Physical Properties of Woven Textures of Straws and Leaves

This section included physical properties of the developed woven textile textures from the straws and leaves. The physical properties which were examined were mass weight (GSM) and thickness of the woven textile textures (NITRA 2016).

GSM and Thickness

The weight **(**GSM) of PSP_1 WSP_2 and DPP_3 was 276.00 g/m^2, 199.90 g/m^2 and 186.00 g/m^2, respectively (Shown Fig 2). Thus, the weight of the woven texture PSP_1 was highest (276.00 g/m^2) comparison to other samples (Table 5). Thickness of DPP_3 was minimum (0.990mm), while thickness of PSP_1 was highest (1.521mm). Low thickness may be preferred for composite textures. Thickness of raw materials affects the thickness of end products.

Table 5: Physical properties of woven textures developed from straws and leaves

Physical properties	Developed woven textures from straws and leaves		
	Paddy straw (PSP_1)	Wheat straw (WSP_2)	Date palm leaves (DPP_3)
Weight (GSM) (g/m^2)	276.00	199.90	186.00
Thickness (mm)	1.521	1.370	0.990

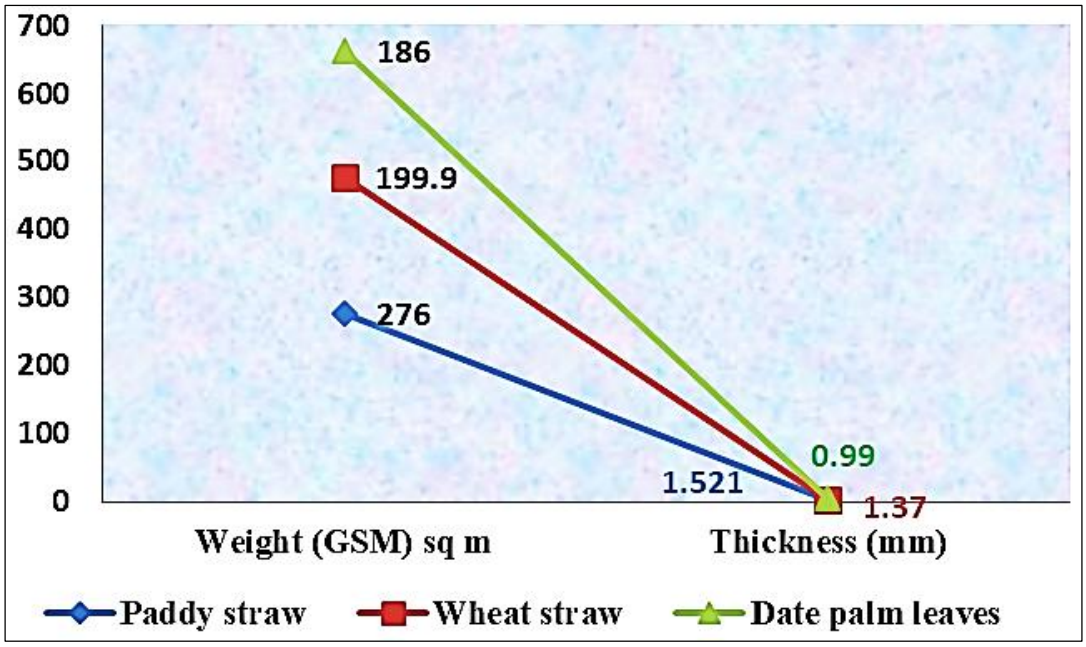


Fig 2: Physical properties of woven textures from straws and leaves

Conclusions

The present study will be useful to motivate the landless and small land holding farmers and farm women to fully utilize plant and agro-waste materials and supplement their income by establishing their own enterprises. The study will provide innovative ideas to craft persons; fashion, textile and interior designers; and merchandisers for development of diversified products from plant and agro-waste materials. The developed samples from selected wheat and paddy straws, and date palm leaves coded as PSP_1, WSP_2 and DPP_3 were found suitable for various end-uses such as coaster plates, bags, purses, file cover, mats, small window curtains, baskets, containers and trays.

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