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Corrugated fibre board boxes from sisal (*Agave sisalana*) - An alternative to wooden packages

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ABSTRACT

A study was taken up to develop a process for making corrugated fiber board boxes from the leafy fibre crop, *Agave sisalana* commonly known as sisal. Cooking pressure of 1.73 kg/cm^2, 3 per cent NaOH concentration and 20 minutes cooking time was found to be the optimum process parameters for producing high strength sisal paper boards. Regular Slotted Container (RSC) type Corrugated Fibre Board boxes of 3 and 5 ply having internal dimensions of 220x110x180mm were made using the developed material. The developed boxes were packed with grapes and tested for their strength under laboratory and field conditions. Free fall test revealed no damage to the boxes. Transportation test proved that 5 ply boxes were better than 3 ply boxes in terms of damage to the box and to the produce. The cost of the box was worked out to be Rs.3.50 where as the cost of the market product is around Rs. 5.75 per box.

Key words : Sisal, Paperboard, Quality, Corrugated fibre board boxes, Laboratory tests, Field tests.

INTRODUCTION

Corrugated Fiber Board (CFB) is the most popular raw material used for transport package of a wide variety of products including fresh fruits and vegetables and is suitable for all different modes of transport. The increased shortage of forest produce due to felling of trees and the strict ban by the Government on deforestation has led to the demand on the package made of wood which is used since time immemorial for transportation of horticultural produce. Non–wood fibrous raw material could fill in this gap/demand where cheap and durable packages are required. Corrugated Fiber Board boxes can considerably reduce the threat of ecological imbalance that may be caused by continuous use of timber.

Sisal also known as 'Agave' is a large genus of short – stemmed half woody plants, bearing a rosette of long, erect, pointed fleshy leaves. The world annual production of sisal is 36,900 MT (Anonymous, 2000). Each sisal plant yields about 250-300 leaves during its lifetime of 7-8 years and sisal fibre is well suited for cordage of all kinds. Sisal contains 64 per cent cellulose, 28 per cent hemi-cellulose, 9 per cent lignin and 0.7 per cent ash (Mitra, 1999). It has been reported that out of the total area of cultivation of this crop, only half the area of cultivation is utilized for extraction of fiber. The crop is left unused in most of the places resulting in loss of fiber and revenue. The fiber has very good resistance to water and microbial attack. The present investigation was taken up to exploit the potential of sisal for making paper boards suitable for the production of corrugated fiber board boxes that can be used for packaging and transportation of fresh produce.

MATERIALS AND METHODS

Process for making paper boards from sisal:

About six kg of sisal leaves of 1-1.5 m length were chopped into small pieces of 5 to 7 cm length. The chopped raw material was cooked in an autoclave at different pressures of 1.38 kg/cm^2, 1.73 kg/cm^2 and 2.08 kg/cm^2 (absolute), respectively. The duration of cooking was varied as 10, 15 and 20 minutes at each pressure. Sodium hydroxide was added at the level of 1, 3 and 5 per cent by weight to the raw material at the time of digestion. The cooked material was washed in water to remove the residual caustic soda and pulped in the beater (Holland type) by adding waste paper to the pulp at different ratios by weight depending on the treatment and also by adding chemicals such as alum, china clay and rosin. The pulp was transferred into a tray at the bottom of an autovat. The free water from the sheets was squeezed out in a hydraulic press. The sheets were then sun dried and the wrinkles on the sheets were removed in a calendaring machine. The paper sheets were cut into desired size in a shearing machine for further testing of quality.

Testing the properties of sisal paper boards:

– The breaking length (B_l) of the paper is the length of a uniform strip just sufficient to cause the strip to break under its own weight when suspended freely from one end. The breaking length of paper is obtained by using the formula :

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$$B_l = \frac{T_S \times 10^5}{GSM}$$

where, B_l -Breaking length, m, T_S - Tensile strength, kg/cm, GSM- substance of paper, g/m^2

– A test piece of known area was brought in contact with water for a specified interval of time and the weight in g of water absorbed per square meter of the surface was taken as an index of the water absorbance of the paper.

– The bursting strength of paper sample was determined by the bursting or pop test, often referred to as the Mullen test. The burst factor (Bf) is calculated as detailed below:

$$B_f = \frac{B_s \times 10^7}{GSM}$$

where, B_f- burst factor, dimensionless, B_s- bursting strength, kg/cm^2, GSM- substance of paper, g/m^2

– The internal tearing resistance was measured by means of pendulum type instrument called Elmendrof Tear Tester. From the tearing resistance, the tear factor (T_f) is calculated as detailed below.

$$T_f = \frac{T_r}{GSM}$$

where, T_f-tear factor, dimensionless, T_r-tearing resistance, g/m^2, GSM-substance of paper, g/m^2

Development of corrugated fiber board boxes from sisal:

By combining two liners to a single corrugating medium, 3 ply boards were formed. Similarly, by combining two fluted corrugated medium with a central liner and then adding two other liner facings, 5 ply boards were formed. Regular Slotted Container (RSC) is the most commonly used style in India, because it is the simplest type to manufacture. For minimum board area, the ratio of L: W: H (length to width to height) is very important and the ratio for minimum board consumption is given below: (Girja and Srivastava, 2000).

L: W: H = 2:1:2, L= 2W, W= W, H=2W

Testing of corrugated fiber board boxes

Free fall test was carried out on individual packages. A sequence of 6 and 12 drops were made. Dropping of carton was done manually. The height of the fall was given by the formula (Ramakumar *et al.*, 1995):

$$H = 70 - P$$

where, H –height of fall, cm, P–weight of the full package, N

Compression testing of corrugated fibre board boxes was carried out using Electronic Tensile Testing Machine (UNITEK Model).

The road transport test of the corrugated fiber board boxes of 3 ply and 5 ply was performed to determine the effect of physical location of the boxes in the carrier on damage to the produce and to the package. Freshly harvested grapes (Muscat variety) from the vineyards were packed in the developed corrugated fibre board boxes and transported through a mini truck to the local market covering a distance of around 30 km. Observations on damage to the boxes including failures, ruptures and bulges and damage to the produce which include fruit split from bunches and fruit burst and bruises were recorded. Based on the initial whole weight and the weight of damaged fruits, the percentage damage of the fruits was calculated. The damage to boxes was assessed based on visual observation.

RESULTS AND DISCUSSION

Mechanical properties of sisal paper boards:

The breaking length was observed to be maximum at 20 minutes cooking time and 3 percent chemical concentration at 1.73 kg/cm^2 pressure. At higher digestion pressure of 2.03 kg/cm^2, the breaking length was found to decrease.

Regression model was developed for the relationship between breaking length and the cooking parameters at various sisal and waste paper blend ratios as shown below:

B_l = -6.311x10^3+4.912x10^{3}P-11.034T + 589.890 C+53.699S-61x103P^2+2.984T^2-57.631C^2-0.328S^2-33.55PT-63.480PC-2.103PS-4.740TC-0.132TS-.301CS (r^2=0.86) .... (1)

where,

B_l -Breaking length, m, P-Pressure, kg/cm^2, T-Cooking time, min., C - Chemical concentration, per cent, S - Sisal component in pulp, per cent

The adequacy of fit for the above model was tested by analysis of variance.

Water absorbency was found to decrease considerably at 20 minutes cooking time at 5 per cent NaOH concentration for 1:1, 2:1 and 3:1 combination ratios of sisal: waste paper. The water absorbency was found to be less with higher chemical concentration. This may be due to the partial delignification of the raw material occurred on soda cooking, since lignin is a hydrophobic material (Naim *et al*., 1980). Paper samples produced at 1.73 kg/cm^2 cooking pressure revealed higher values of burst factor at a higher chemical concentration and cooking time. Maximum value of burst factor was obtained at 5 per cent level of NaOH and 15 minutes cooking time for sisal and waste paper ratio of 3:1. Similarly highest value of tear factor was recorded for the blend ratio of three parts of sisal and one part of waste paper. Samples produced at NaOH concentration of 3 per cent, resulted in highest tear factor value at 1.73 kg/cm^2 cooking pressure.

Optimisation of process condition for making sisal paperboards:

It has been reported that manufacturers of fiberboard for fruit packages select the liner papers or corrugated medium because for their high tensile strength (Anonymous, 1995). Considering the above fact, the paperboards having maximum breaking length as the main strength characteristic was taken as the best one. This was selected as per the experimental design using factorial completely randomized design procedure. The interaction effect between pressure and cooking time showed that cooking time of 20 minutes resulted in good strength (breaking length) at a pressure of 1.73 kg/cm^2. Similarly the interaction between pressure and NaOH concentration proved that 3 per cent NaOH concentration, the paper samples showed good results. The overall, interaction effects of all the treatments also showed that the sample having sisal: waste paper blend ratio of 3:1, cooked with 3 per cent at the pressure of 1.73 kg/cm^2 for 30 minutes, produced paper boards of maximum breaking length (Table1).

Corrugated fibre board boxes from sisal paper boards:

The boxes were designed for packing 2 kg of grapes. Based on bulk density of grapes, (368.50 kg/m^3), the box dimensions were arrived as L = 220 mm, W= 110 mm, H= 220 mm. B type vertical flutings were made. The corrugated medium was then pasted to the liner board using starch based adhesive based on the number of plies required. The boards were then cut at the sides. Corrugated Fibre Board boxes were made based on the designed values. Body scores and slots were then made. (Table 2)

Laboratory and field testing of corrugated fibre board boxes:

The boxes were packed with grapes and dropped sequentially 6 and 12 times from a height of 50 cm on a flat platform. The fruits were examined for their bursts

Table 1: Effect of cooking parameters on the breaking length of sisal paper

Sisal : Waste paper ratio	Breaking length (m) NaOH concentration (per cent) 1	3	5	W - mean
P= 1.38 kg/cm^2, T = 10 min.				
1:0	372.83	412.79	447.79	411.14
1:1	330.67	399.03	643.96	457.89
2:1	454.24	633.97	751.17	612.91
3:1	566.74	622.97	881.74	690.47
P= 1.38 kg/cm^2, T = 15 min.				
1:0	499.38	769.71	958.51	742.59
1:1	572.13	789.49	896.87	752.83
2:1	673.24	906.56	928.92	836.24
3:1	811.15	1034.76	1125.66	990.53
P= 1.38 kg/cm^2, T = 20 min.				
1:0	534.56	668.98	745.93	649.83
1:1	614.81	798.78	730.52	714.71
2:1	630.46	860.02	781.02	757.17
3:1	662.08	1025.56	944.44	877.36
P= 1.73 kg/cm^2, T = 10 min.				
1:0	404.73	675.01	411.43	497.05
1:1	353.72	885.00	424.77	554.50
2:1	732.03	970.69	744.34	815.69
3:1	805.61	1039.42	752.10	865.71
P= 1.73 kg/cm^2, T = 15 min.				
1:0	279.50	800.61	561.63	547.25
1:1	517.42	1046.73	948.90	837.68
2:1	645.21	1206.25	1011.87	954.44
3:1	661.88	1362.48	978.42	1000.93
P= 1.73 kg/cm^2, T = 20 min.				
1:0	870.16	1070.51	637.33	859.33
1:1	943.219	1330.83	1155.68	1143.77
2:1	960.69	1308.30	1156.69	1141.89
3:1	974.64	1357.87	1194.31	1175.61
P= 2.03 kg/cm^2, T = 10 min.				
1:0	379.46	1092.18	791.33	754.32
1:1	379.93	1372.52	859.09	870.51
2:1	679.80	1390.97	976.43	1015.73
3:1	726.87	1349.18	916.74	997.59
P= 2.03 kg/cm^2, T = 15 min.				
1:0	291.53	577.73	348.78	406.01
1:1	340.27	444.87	405.73	396.96
2:1	317.14	830.28	705.40	673.93
3:1	452.77	971.53	726.15	738.27
P= 2.03 kg/cm^2, T = 20 min.				
1:0	756.39	986.26	587.62	710.09
1:1	1159.43	950.80	743.66	951.30
2:1	962.23	889.95	725.92	859.36
3:1	1062.75	890.00	866.91	939.88
N – Mean	621.65	931.17	796.38	783.37

SED	LSD (5%)	LSD (1%)
52.27	103.01	135.80

Table 2 : Specification of corrugated fibre board boxes

Sr. No.	Specifications	CFB – I	CFB - II
1.	Material of construction	3 ply	5 ply
2.	Capacity	2 kg	2 kg
3.	Style of box	RSC 0201	RSC 0201
4.	Internal dimensions (mm)	220x110x180	220x110x180
5.	Direction of flutes	Vertical	Vertical
6.	Type of flute	B	B
7.	Grammage of plies (GSM)	176	176
8.	Bursting strength (kg/cm^2)	3.6	5.2
9.	Compressive strength (kg)	175	250
10.	Cobb value (g/m^2)	124	165
11.	Flap bend test	No damage	No damage
12.	Type of adhesive	Starch based	Starch based
13.	Joints	Stapled	Stapled
14.	No. of ventilation holes	8	8
15.	Diameter and position of holes	20 mm (long walls)	20 mm (long walls)

and splits. The maximum percentage damage observed was 2.7 per cent for 12 drops for 3 ply corrugated fibre board boxes. Corrugated fibre board boxes of 5 ply exhibited less damage during drop test. The drops did not make any damage to the cartons (3 ply and 5) which mean that these boxes could withstand handling abuse. Deformation was found to be nearly linearly related to the compressive load up to 50 kg (Fig.1). Corrugated fibre board box of 5 ply had a stacking strength of 250 kg but 3 ply box failed early at 175 kg. There was an increase in the compression load taking capacity due to the increased ply rating. The Corrugated Fibre Board boxes of 3 ply and 5 ply were evaluated for their performance under dynamic transport conditions. The magnitudes of damage to 3 ply Corrugated Fibre Board boxes was more than 5 ply CFB boxes. However, the product damage was very minimum or negligible. In the case of 5 ply boxes, the boxes maintained their structural stability during transport and there was no product damage in all the 5 ply Corrugated Fibre Board boxes tested. The cost of one box made from sisal paper board was worked out to be Rs.3.50 where as the cost of one box available in the market was around Rs. 5.75 per box.

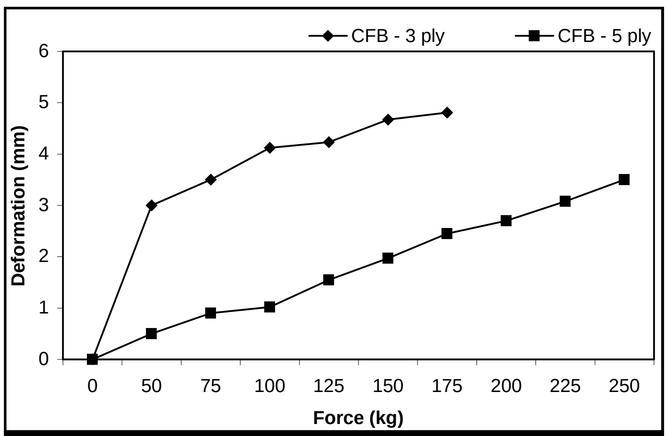

Fig. 1 : Force deformation curve of CFB boxes

Conclusion:

An attempt was made to produce CFB boxes from sisal paper boards as an alternative to wooden packages. The sample having sisal: waste paper blend ratio of 3:1, cooked with 3 per cent at the pressure of 1.73 kg/cm^2 for 30 minutes, produced paper boards of maximum breaking length, which decides the strength of paper board. Corrugated Fibre Board boxes of 3 ply and 5 ply having 2 kg capacity were designed. Laboratory and field tests of the CFB boxes packaged with grapes revealed that 5 ply boxes were better than 3 ply boxes.

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