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Valorization of Pineapple Waste for Development of Animal Feed Block

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A B S T R A C T

The present paper explores the feasibility of transforming a composite of pineapple waste compressed with paddy straw into an animal feed block. Four ratios of pineapple waste and paddy straw were attempted, *viz.*, FB_1 (0:100), FB_2 (10:90), FB_3 (20:80) and FB_4 (30:70) with molasses (10%) as a binding agent, compressed at different compression pressures (13.78, 20.68 and 27.58 MPa) to square feed blocks (8 x 8 cm). Different feed blocks were evaluated for their physical properties, *viz.*, bulk density, resiliency, hardness and compression ratio, and their values ranged from 482.13 to 647.87 kg/m^3, 23.79 to 29%, 66.28 to 106.34 N and 8.56 to 11.17 respectively. A compression pressure of 27.58 MPa in FB_4 was found to be appropriate combination for a stable, denser and resilient feed block. Development of feed blocks from pineapple waste can serve as promising eco-friendly opportunity for comprehensive utilization of food processing waste for high resource utilization and environmental mitigation.

Introduction

In recent years, valorization of agro processing by-products and residue has become an area of intensive and hectic industrial research for developing a sustainable food system. Fruit and vegetable processing waste (FVW) are high in moisture, organic effluent and thus prone to microbial spoilage. Their disposal represents a major challenge for processing industries. It is estimated that nearly 55 million tonnes of FVW is generated annually in supply chain of fruits and vegetables in India, Philippines, China and USA (FAO, 2013). A large proportion of these wastes are dumped in landfills or rivers, causing serious environmental hazards. Alternatives to such disposal problem could be recycling through livestock as feed resources or development of value added products. Utilization of FVW for livestock feed will help in augmenting and enlarging the existing feed resource, particularly those not competing with human food.

Pineapple is one of the major fruit consumed all over the world and is largely processed in forms of rings, juice and concentrate. The processing waste from pineapple processing industry constitutes 50 percent of the total fruit, and largely includes peel, core, trimmings, shreds, crown and leaves. The waste solid and liquid sludge rich in organic material, carbohydrates, and fiber poses a serious environmental problem for pineapple industry (Ketnawa *et al.,* 2012). Pineapple waste has been largely investigated for extraction of bromelain, vinegar, ethanol, citric acid, methane and antioxidant compounds (Kumar *et al.,* 2003; Omojasola *et al.,* 2008).

Dried pomace of FVW, mixed with dried foliage (rice and wheat) has the potential of being compressed into dense feed blocks for animals. 'Feed block technology' also known as densification of roughage based crop residues is a process wherein by-product can be converted into compact blocks as animal feed. The compressed feed blocks offer numerous advantages when compared to mash or pelted feeds. They involve less electrical energy consumption and preparation cost, reduced cost of transportation and storage, and can offer assistance to fodder banks to be set up in times of flood or drought.

Recently there have been few reports on development of feedblock using composite of mustard straw, wheat straw, berseem hay, groundnut haulm, barley, canola and oats (Singh *et al.,* 2004; Adapa *et al.,* 2009;Afzal *et al.,* 2008), andfresh banana foliage up to 15 percent (El-Ghani, 1999).Dried foliage ensiled with dried broiler litter in aratio of 40:60 and rehydrated with either molasses or whey, included at 15 percent (Khattab *et al.,* 2000), could replace 50 percent of green maize in the rations of lactating cows/buffaloes. Keeping in view, the above facts and necessity of exploring novel feed resources, we have attempted to develop a composite animal feed block using pineapple waste and paddy straw. The intent was to provide an alternative for huge waste disposal problem of food processing by-products as livestock feed resource.

Materials and Methods

A laboratory model vertical compression machine with a hydraulic cylinder as the compactor was used to develop a pineapple basedfeed block (Singh *et al.,* 2002).The machine has been indigenously developed at Division of Agriculture Engineering, Indian Agricultural Research Institute, New Delhi-12.The machine consists of hydraulic cylinder, power pack, compaction chamber and frame and has maximum working pressure of 419 kg/cm^2. The typical hydraulic machine has its vertical crosshead fitted with a piston punch to fit into the compaction mould for load application. Pineapple waste (crown, peel and pomace) and chopped paddy straw (30 mm) were initially dried to moisture content of 8.69% (w. b.) and mixed with 10% molasses (binding agent). Four ratios of pineapple waste and paddy straw were attempted, *viz*., FB_1 (0:100), FB_2 (10:90),FB_3 (20:80) and FB_4 (30:70). Combination of 100% paddy straw with molasses served as control (FB_1). Each feed block was subjected to three levels of compression pressure (13.78, 20.68 and 27.58 MPa). For development of feed blocks, different combinations of paddy straw, pineapple waste and molasses were taken and filled in a compression mould of 8x 8 cm cross-sectional area. A vertical load was applied on the sample still it reached desired pressure levels, which was monitored on the fitted pressure gauge. The feed blocks were evaluated for bulk density (ρ_b), resiliency (R) and hardness (H) after 24 h, and compression ratio (CR) at 0h.

The moisture content of the pineapple waste and paddy straw was determined by gravimetric method and expressed in percent wet basis (% w.b.). A sample of 10 g was ovendried at 103 ± 2°C and weighed after each 30 min interval till 2 consecutive readings were constant (AOAC, 2005).

The bulk density of the compacted block was calculated with the sample weight and the measured volume. It was calculated using Eq. 1.

$$\rho_b = \frac{W}{L \times B \times T} \ldots (1)$$

The compression ratio was obtained from the ratio of bulk density of compact block to the initial density of the material being compressed and calculated using Eq. 2.

$$CR = \frac{\rho_b}{\rho_{raw}} \ldots (2)$$

Resiliency (length recovery) indicates the elastic property of the material. It is determined as the ratio of increase in thickness after 24 h to the initial thickness of the block. It was calculated using Eq. 3.

$$R = \frac{T - T_i}{T_i} \times 100 \ldots (3)$$

After the blocks were removed from the compaction mould, the thickness of the blocks which varied with time, were measured initially at 5 min interval up to 30 min and then after 1 and 24 h, respectively.

Hardness indicates the degree of binding and was measured by a Texture Analyser (model: TA+Di, Stable micro systems, UK) with a 500 kg load cell and 75 mm diameter compression plate. Feed blocks were compressed to 50% of their total height at a crosshead speed of 2 mm/s and hardness (N), defined as the maximum peak force (Kgf) during the compression, was recorded (Bourne, 1978).

The variables for feed block preparation were subjected to analysis of variance (ANOVA) using the linear model method. Linear regression equation was obtained for each of the dependent variables using SPSS16 statistical package. Response surface curve graph was generated with surfer6 software. All treatments were taken in triplicates.

Results and Discussion

The effect of compression pressure on bulk density of feed block at different levels of pineapple waste addition is presented in Figure 1. Bulk density of the feedblocks showed linear increase with increase in compression pressure and varying ratio of pineapple waste. Maximum bulk density was observed at 27.58 MPa compression pressure which ranged from 594.86 to 647.87 kg/m^3(Table 1). The bulk density of uncompressed mass (pineapple waste, paddy straw and molasses) ranged from 66.52 to 82.48 kg/m^3. Analysis of variance confirmed the positive effect of both compression pressure and pineapple waste on bulk density.

$$\rho = 391.163 + 7.159 \times P + 2.046 \times W$$

$$(R^2 = 0.990) \quad \ldots(4)$$

The addition of molasses caused a drastic increase in the compressibility of paddy straw because of its binding property. Our results are in agreement with results of feed block based on crop residues *viz.* wheat, paddy straw, mustard, gaur, bagasse (Singh *et al.*, 2005; Samanta *et al.*, 2004). A similar relationship of bulk density with compression pressure has been reported for wheat, barley and rice straw up to a compression pressure of 6 MPa by Ferrero *et al.*, (1990).

The values of resiliency in different feed blocks compressed at varying compression pressures ranged from 23.79 to 29.00% after 24 h (Table 1). Resiliency indicates the tendency of a compressed feed block to expand in volume and higher the resiliency, less stable is the compressed block. FB_1 showed highest resiliency, which is due to the fact that paddy straw is a cellulosic material and highly visco-elastic in nature showing high elastic recovery accompanied by slow stress relaxation process (Mohsenin and Jaske, 1975). Resiliency was measured with progression of timewhich decreased with an increase in compression pressure and ratio of pineapple waste. There was an increase in resiliency during the initial 30 min period and subsequently decreased slowly till 24 h.FB_4 compressed at 27.58 MPa pressure was least resilient (23.79%), suggesting its higher stability (Fig. 2). Analysis of variance showed negative effect of both compression pressure and pineapple waste onresiliency.

$$R = 31.207 - 0.131 \times P - 0.125 \times W$$

$$(R^2 = 0.954) \quad ...(5)$$

Wamukonya and Jenkins (1995) reported maximum expansion in wheat straw briquettes up to 2 h. A maximum resiliency (10 to 30%) was reported in compressed cotton stalks within 30 min, followed by a slow decrease (3 to 11%) till 24 h (Jha *et al.*, 2008). Similarly, O'Dogherty and Wheeler (1984) reported a total relaxation of 56 to 60% within 1 h in wheat and oilseed rape straws.

Compression ratio is indicative of the reduction in volume as a result of compaction, it helps in prediction of reduced savings in transportation and storage, by the same factor of volume reduction. Maximum value was observed in FB_1 at 27.58 MPa (11.17), however, with increasing levels of pineapple waste significant reduction in compression ratio was observed, with the lowest value of 8.56 in FB_4 at 13.78 MPa (Table 1). This suggests that, by densification of pineapple waste with paddy straw into a feedblock, we could nearly save 8.56 to 11.17 times on storage space, handling and transportation costs. Analysis of variance showed that both compression pressure and pineapple waste had significant effect on compression ratio.

$$CR = 7.979 + 0.097 \times P \ 0.026 \times W$$

$$(R^2 = 0.776) \quad ...(6)$$

The compression ratio increased with an increase in compression pressure but decreased with increase in the percentage of pineapple waste (Fig. 3). This may be due to less bulky nature (higher bulk density) of the pineapple waste since it has lesser volume as compared to paddy straw. This is considered as an advantage of the compression process. Singh *et al.*, (2012) reported on compression ratio of paddy straw and showed it compressed to 45 times in a briquetting machine. Compression ratio of cotton stalk blocks varied from 5.2 to 8.6 suggesting a maximum of 8.6 times savings in storage and transportation (Jha *et al.*, 2008).

Hardness in feed block ranged from 66.26 to 106.34 N (Table 1). The effect of varying compression pressure and percentage of pineapple waste on the hardness of feed block is shown in Figure 4. Analysis of variance showed significant effects of compaction pressure and pineapple waste on hardness.

$$H = 69.164 + 1.181 \times P - 0.713 \times W$$

$$(R^2 = 0.944) \quad ...(7)$$

With an increase in compression pressure, the hardness of the feed block increased at the same volume of material and irrespective of ratio of pineapple waste. However, reverse was observed with increasing levels of pineapple waste progressing to 30%. This may be due to the less elastic nature of the dried pineapple waste as compared to paddy straw which is more visco-elastic in nature. This elasticity of paddy straw might have led to more requirement of force (N) to break the feed blocks, as it is evident that 100% paddy straw feed block showed highest hardness at different compression pressure. A similar relationship between die pressure and briquette strength for sawdust, rice husk, peanut shell, coconut shell, and palm fibre briquettes was reported by Chin and Siddiqui (2000). With compression pressure ranging from 29 to 34.47 MPa, compressed cotton stalks showed a linear increase in hardness with an increase in pressure (Jha *et al.*, 2008).

Effect of 2 month storage period on the property of the feed block was evaluated. There was no measureable change in bulk density and resiliency (data not shown), however, it was observed that there was slight decrease (2.35 to 5.74%) in hardness of the feed blocks (Table 1). This decrease in hardness may be because of desiccation and consequent decrease in binding ability of molasses in the feed blocks due to low ambient RH and high temperature. All the feed blocks showed high stability reflecting its durability during storage which might be due to the addition of molasses that binds the materials during blocking (Sihag *et al.*, 1991) and a combination of pineapple waste.

Table.1 Effect of compaction pressure and different levels of pineapple waste addition on bulk density, resiliency, compression ratio and hardness of feed block

Compression pressure (MPa)	Treatment	Bulk density (Kg m^{-3}) 24 h	Resiliency (%) 24 h	Compression ratio 0 h	Hardness (N) 24 h	Hardness (N) 2 months
13.78	T_4	482.13 ± 0.98	29 ± 1.01	9.05 ± 0.12	86.06 ± 0.41	82.01 ± 1.07
	T_1	512.94 ± 0.75	28.83 ± 0.27	8.86 ± 0.03	75.61 ± 0.66	72.14 ± 0.85
	T_2	531.17 ± 2.72	26.92 ± 0.44	8.72 ± 0.17	71.54 ± 0.88	68.53 ± 0.34
	T_3	553.63 ± 1.04	25.79 ± 0.16	8.56 ± 0.15	66.28 ± 0.53	64.08 ± 0.74
20.68	T_4	541.92 ± 0.29	28.24 ± 0.7	10.02 ± 0.22	94.99 ± 0.72	89.53 ± 0.43
	T_1	562.83 ± 1.85	26.94 ± 0.41	9.95 ± 0.19	83.51 ± 0.97	79.58 ± 0.41
	T_2	573.78 ± 0.89	25.77 ± 0.57	9.74 ± 0.16	77.77 ± 1.27	74.16 ± 0.86
	T_3	605.24 ± 1.77	24.62 ± 0.48	9.59 ± 0.13	74.34 ± 0.66	72.59 ± 0.41
27.58	T_4	594.86 ± 1.10	27.84 ± 0.44	11.17 ± 0.24	106.34 ± 0.56	100.58 ± 1.16
	T_1	605.57 ± 1.05	26.79 ± 0.33	9.95 ± 0.19	91.61 ± 0.87	87.47 ± 1.13
	T_2	626.72 ± 3.94	24.89 ± 0.45	9.75 ± 0.13	86.15 ± 1.07	83.08 ± 0.19
	T_3	647.87 ± 0.55	23.79 ± 0.38	9.68 ± 0.16	80.61 ± 0.53	77.58 ± 0.98

Mean values with standard deviation; n=3

Fig.1 Effect of compaction pressure on bulk density of feed block at different levels of pineapple waste addition

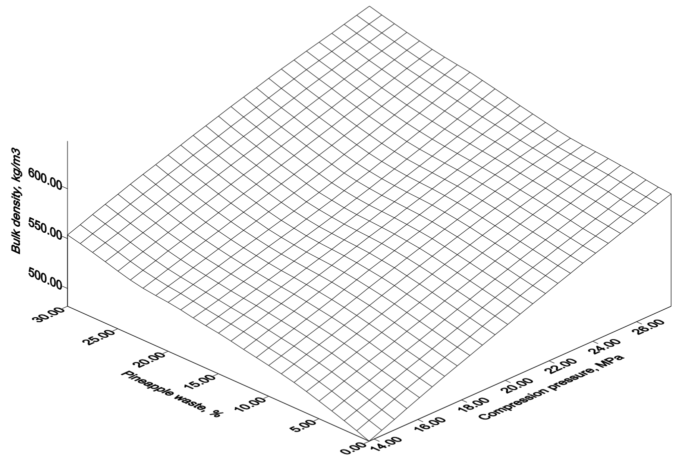


Fig.2 Effect of compaction pressure on resiliency of feed block at different levels of pineapple waste addition

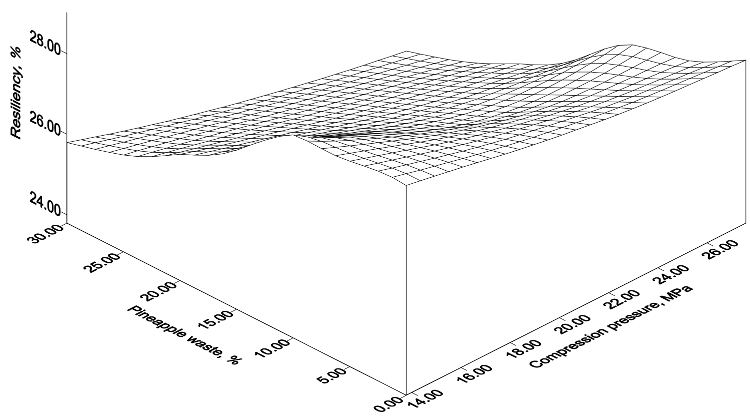


Fig.3 Effect of compaction pressure on hardness of feed block at different levels of pineapple waste addition

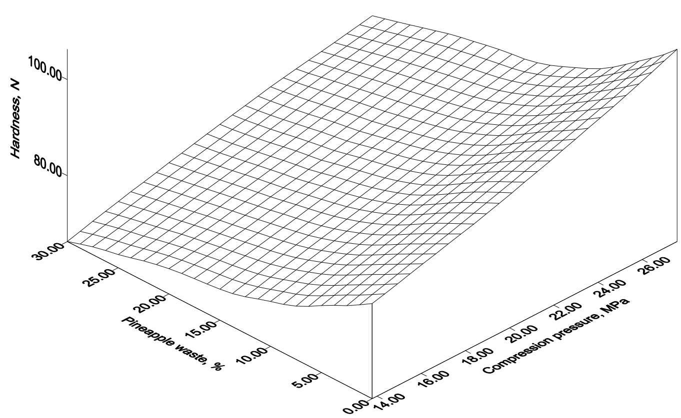
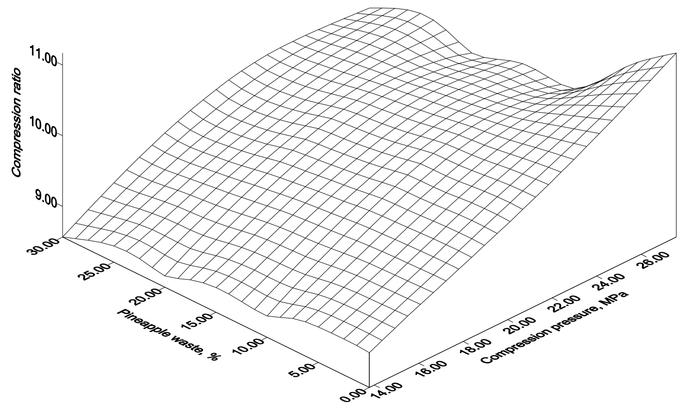


Fig.4 Effect of compaction pressure on compression ratio of feed block at different levels of pineapple waste addition



Hozhabri and Singhal (2006) found that complete feed blocks (wheat straw and sugarcane bagasse) packed in HDPE bags did not show any measureable post compression expansion even after 30 d of storage. As Das *et al.,* (2005) and Jaglan and Kishore (2005) have reported low durability of paddy straw alone based feed blocks compared to other roughage sources. None of the feed blocks revealed any visible mould growth at any stage during storage. This might be ascribed either to the low moisture content of the feed blocks as well as due to the low ambient RH and high temperature during the storage period. Similar findings with respect to low moisture content of feed block and stability were reported by Afzal *et al.,* (2008) in complete feed block (paddy straw, maize and oat) and Singh *et al.,* (1998) in be seem based feed block.

It is concluded at 27.58 MPa compression pressure and 30% pineapple waste, the bulk density was maximum, hardness increased, compression ratio decreased whereas the resiliency was least, this feed block was found to be the most appropriate and contributed maximum to the stability of the compressed block. The volume of feed blocks could be reduced up to 91% by compaction and addition of pineapple waste. These feed blocks are convenient to handle, and saves on storage, handling and transportation.

Symbols

ρ_b bulk density of pineapple waste and paddy straw feed block, kg/m^3

ρ_{raw} bulk density of loose pineapple waste and paddy straw, kg/m^3

CR compression ratio

R resiliency, %

H hardness, N

W weight of pineapple waste and paddy straw, kg

L length of pineapple waste and paddy straw, mm

B breadth of pineapple waste and paddy straw, mm

T thickness of stabilized pineapple waste and paddy straw feed block, mm

Ti initial thickness of pineapple waste and paddy straw feed block, mm

w.b. wet basis
h hour

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