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Developing and performance evaluation of a hydraulic press for animal feed blocks formation

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ABSTRACT

An appropriate machine prototype was developed and evaluated for densification of rice straw with molasses into animal feed blocks, to enable efficient utilization of rice straw, and to improve the feed bulk handling, transportation, and storage properties. The machine prototype involved two main parts namely: hydraulic press and compactor parts (mold, rammer and free base). The feed raw material samples were densified under the effects of four pressure levels (24.52, 34.32, 44.13 and 53.94MPa), two geometrical mold shapes (cube and cuboid), four molasses content levels (4, 6, 8 and 10%), and three moisture content levels (about 10.32, 13.41 and 16.58%, w.b.) by a piston-mold process. The properties of the densified animal feed blocks were illustrated with respect to bulk density, densification degree, resiliency, durability and stiffness. Also the performance of densification machine prototype was evaluated in terms of its productivity and cost unit. Results indicated that, the optimum conditions for producing good quality densified feed blocks, were obtained by applying hydraulic pressure of 53.94MPa, molasses content of 10% and straw moisture content of 16.58%. As densification process was carried out respectively in cube and cuboid molds under these variable levels, the produced feed blocks, exhibited respectively: bulk densities of 659.87 and 632.04kg/m^3, densification degrees of 281.41 and 265.32% and resiliency indicates of 8.35 and 10.03%. The results also indicated that, the highest durability values of 99.27 and 96.92% were respectively obtained for both densified cube and cuboid blocks at moisture content of 10.32%, compression pressure of 53.94MPa and molasses content of 10%. At the same mentioned densification conditions, the highest block stiffness values (385.22 and 380.86N), were respectively obtained for both densified cube and cuboid blocks. For choosing a proper geometrical mold shape, the results reveled that the densified cube blocks were high stability compressed blocks compared to cuboid blocks. The average productivity of the investigated feed block formation equipments was 60 feed block/h (45kg/h), while, the machinery unit cost was about 8.144LE/h (0.18097LE/kg).

INTRODUCTION

Crop production in Egypt has achieved new feats. This has simultaneously led to increased production of crop residue (e.g. rice straw), which are usually considered as waste despite their huge potential for utilization as fuel, feed and chemicals. The major problem associated with the residues is their low bulk density, which causes a serious problem in their handling and transportation. This leads to the problem of residue disposal during the harvest season. Consequently, most farmers prefer to burn them in the field, which leads to environmental pollution and loss of income that could otherwise be realized through their potential use. It is, therefore, felt that densification of these residues to an economical level is very important for their further use. There are several densified technologies like briquetting, pelleting and baling which are in use in Egypt. However, these processes have been found to be useful for crop residues only to a limited extent. In a hunt for a better process, animal nutrition experts, through much research have suggested that the crop residue could profitably be used as animal feed by mixing with diet supplements like concentrates, molasses and mineral mixtures and densifying the mixture (*AbouElmaged et al., 2003; AboSalim and Bendary, 2005 and Ghanem et al., 2005*). However, lack of a suitable machines for crop residues densification into animal feed blocks. *O'Dogherty and Wheeler (1984)* studied the compression of straw and grass in the closed dies at pressures in the range of 12-31MPa and established a pressure density relation for the straw and reported the optimum moisture content for the wafer formation as 10-20% (w.b.). *Ferrero et al. (1990)* reported that the pressure-density behaviour of wheat, barley and rice straws of different moisture contents during compression in a cylindrical die at pressures of 20-100MPa. It was also reported that up to 6MPa pressure range, the relationship between density and pressure was linear, beyond which nonlinear relationship appeared. Durability or abrasive resistance test simulates either mechanical or pneumatic handling. These tests can help control the densification process and, thus, block quality in the feed manufacturing industry. In the feed industry, high durability means high quality blocks *(Kaliyan and Vance Morey, 2009)*. *Al-Widyan et al. (2002)* studied the quality of the densified products in terms of briquette/pellet durability and stability. Highly durable and stable pellets/briquettes are less susceptible to breakage during handling, transportation and storage. A durability index is determined to simulate the ability of pelleted and cubed material to withstand the impact force and vibration generated during handling. Stability is the ability of the product to maintain its initial dimension and shape. *Ndiema et al. (2002)* reported that there was considerable influence of the die pressure on the size and form of briquettes. For a given die size and storage condition, there was a maximum die pressure of 80MPa beyond which no significant gain in the cohesion of briquette could be achieved. *Singh et al. (2002)* reported a minimum 4-5 times increase in bulk density of roughage-based feed materials, with an increase in compression pressure from 21 to 42MPa during the densification process in the form of blocks. Compaction is the process of densification that decreases the pore size and porosity and causes particle rearrangement by means of impact energy. The compaction of agricultural residues is a value adding process. Compaction of straw from different crops, with additives of molasses, minerals, concentrates and other diet supplement, into animal feed blocks and pellets is highly useful in animal nutrition management, transportability and storage. Nutritionally, molasses is used as an energy source. Molasses is a useful ingredient for improving the palatability/digestibility of the diet and serving as a binder. In pellets or blocks production for animal feed, binders are allowed but need to be specified as part of the final product. Examples of good binding materials are molasses, starch, fish waste, manure and maize or wheat bran. Compaction of fodders and straws into large blocks could save the storage space and transportation cost by the same factor as achieved in the compaction process (*Sarwar et al., 2002; Khan et al., 2003 and Tumuluru et al., 2010*). Therefore, the general objective of the present study was to manufacture and evaluate the densification performance of local equipments for animal feed block formation from rice straw, while the specific objectives were:

- Develop a vertical hydraulic press with a piston/mold parts as densification machine prototype.
- Determine the optimum conditions for densification, with respect to applied hydraulic pressure level, moisture level, molasses additive level and also the geometrical shape of formation mold.
- Evaluate some the physical properties of the compressed blocks.
- Estimate the productivity and unit machinery cost of feed block formation equipments.

MATERIALS AND METHODS

The developed densification machine prototype was developed based on the principle of hydraulic compression for making feed blocks. Whereas, a vertical hydraulic press with a piston-mold equipments were used as the compactor.

Hydraulic press, molds and rammers:

A hydraulic press is a machine using a hydraulic cylinder to generate a compressive force. The Japanese type hydraulic press (Model No., HP-50E) was used in this work. It consisting of a cylinder fitted with a piston that uses fluid (hydraulic oil) under pressure to exert a compressive force upon a stationary anvil or base plate. The fluid is forced into the cylinder by a pump. Hydraulic press include four legs mounted on a pair feet connected at the bottom by a cross brace. It has loads capacity to apply pressure up to 58.48MPa (600kg/cm^2). Molds and rammers were manufactured to form the animal feed blocks. They were accomplished at private workshop in Kafrelsheikh governorate, Egypt. Two geometrical shapes of mold namely: cube and cuboid were used in this research. Molds were built from iron sheet with 4mm thick. The dimensions of the cube mold was (17x17)cm of cross-sectional area and 15cm high. Four cubic molds were formed and were constructed as one unit to produce four blocks of animal feed at the same time. While, the cuboid shaped mold with cross-sectional area of (12x24.083)cm and 15cm high. Also, Four cuboid shaped molds were formed and were fabricated as one unit to produce four blocks with each other. Two molds (cube and cuboid) have equal values from the calculated area and total volume. The plungers were constructed of the welded steel angles (50x50)mm with four rammers from flat iron sheet (5mm thick) to fit into the compaction molds for load application. The vertical load was applied manually on the sample until the desired pressure level was achieved. The pressure was read off the dial of a pressure gauge. The block samples were made by compressing the rice straw/molasses with a piston and molds assembly. These procedures are done by placing the molds on the table of the hydraulic press, aligning the plungers/rammers with the location on the molds where the procedure needs to be done and placing the piston into motion (manually) and the procedure is accomplished (Figs. 1, 2 and 3).

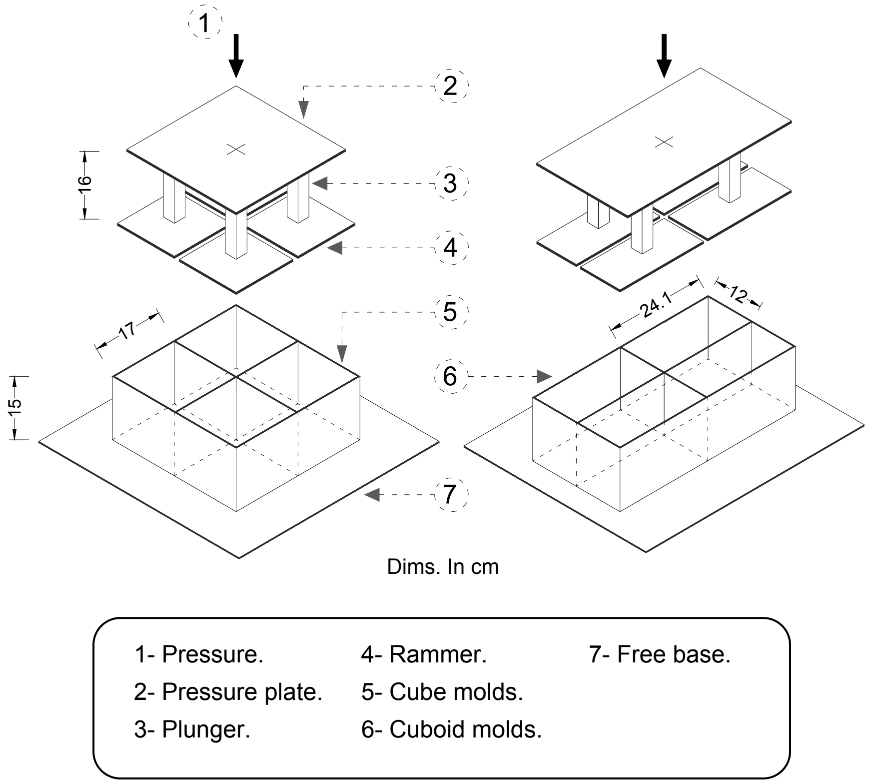
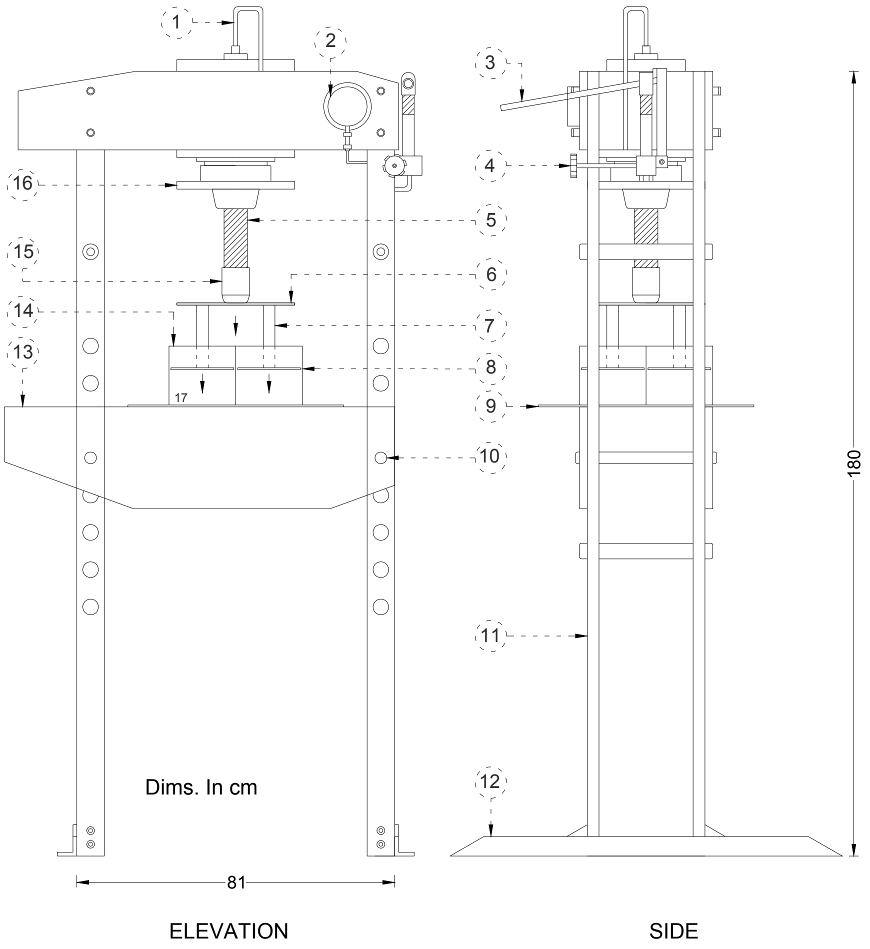


Fig. 1: Engineering drawing of the cube and cuboid molds.

Fig. 2: Photographs view of the cube and cuboid molds.



1- Oil tube.
2- Pressure gauge.
3- Pump handle.
4- Release valve.
5- Extension screw.
6- Pressure plate.
7- Plunger.
8- Rammer.
9- Free base.
10- Table pin.
11- Frame.
12- Press feet.
13- Work table.
14- Cube molds.
15- Press head.
16- Hand wheel.
17- Raw material.

Fig. 3: Schematic diagram of the hydraulic press with cube molds.

Raw material:

Rice straw (Sakha 101 variety) samples were collected and dried in a solar dryer (passive aeration type) until they reached to desired moisture contents (of about 10.32, 13.41 and 16.58%, w.b.). the dried straw samples were chopped into about 1-3cm segments to be tested in all the experimental treatments. Different proportions of sugarcane molasses (4, 6, 8 and 10%, from mass of rice straw) were mixed with rice straw for various its moisture content. It was regarded that, the maximum molasses content was kept such that no oozing of molasses was caused through application of high pressure level. To study the optimum conditions for densification and also the compression characteristics for rice straw with molasses, special regime of experiments were carried out during the year of 2014 at Rice Mechanization Center, Meet El-Deeba, Kafrelsheikh Governorate, Egypt.

Investigated variables:

The plan of the group of experiments was essentially designed and carried out to acquire some indicators which judge the piston-mold process by the hydraulic press. Those indicators are the physical characteristics of the compact blocks, such as bulk density, densification degree, resiliency, durability and stiffness under the investigated variables. The Investigated variables and their levels were as follows:

- Two geometrical shapes of mold namely: cube and cuboid;
- Four compression pressures of 24.52, 34.32, 44.13 and 53.94MPa;
- Four molasses content of 4, 6, 8 and 10%. and,
- Three moisture content of rice straw of about 10.32, 13.41 and 16.58%, w.b.

Measurements:

Moisture content of rice straw:

The moisture content of rice straw was determined before densification process, using the oven method (at about 70°C to constant mass) according to *ASAE standard, 1998*.

Bulk density of feed blocks:

Bulk density is an indicator of savings in storage area, transportation space and cost of blocks. The bulk density of the compacted blocks was calculated with the sample mass and the measured volume in each treatment. The volume was determined by the cross sectional area and thickness variables of the blocks. The thickness of blocks, which varies during post-compression recovery, after 24h was used to calculate the stable density of blocks according to *Singh, et al., 2005 and Jha et al., 2008*. The bulk density of the un-compacted samples (initial bulk density) of the chopped rice straw was evaluated at different levels of molasses content and moisture content. The average determined initial bulk density was about 173.01±1.384kg/m^3. The un-compacted density was used for the comparisons with the bulk density of the corresponding compacted blocks.

Densification degree of feed blocks:

Degree of densification is defined as percent increase in density of blocks due to compressing. Degree of densification represents ability of material to get bind, that degree was determined according to *Ghorpade and Moule, 2006*, using equation, 1.

$$Densification\ degree = \frac{Bulk\ density\ of\ feed\ block - Initial\ bulk\ density}{Initial\ bulk\ density} x\, 100,\% \quad \ldots\ldots\ldots\ldots\ldots.. (1)$$

Resiliency of feed blocks:

After the block was removed from the compaction mold, the resiliency (length recovery) was measured with time, varying from 5min to 24h. Resiliency indicates the elastic property of the material. It was determined as the ratio of increase in thickness to the initial thickness of the block (equation, 2). The thickness of the blocks, which varied with time, was measured initially at 5min intervals up to 30min and then after 24h according to the method of *Singh, et al., 2005 and Jha et al., 2008*.

$$Resiliency = \frac{Thickness\ of\ stabilized\ block - Initial\ thickness\ of\ block}{Initial\ thickness\ of\ block} x\, 100,\% \quad \ldots\ldots\ldots (2)$$

Durability of feed blocks:

Durability is the most important aspect of block quality. It means the ability of blocks to withstand the rigors of handling and delivery without breaking-up (*Payne, 2006*). The durability of blocks was determined according to *ASAE standard, 1998*. The tumbling device was used for testing purpose under 40rpm for three minutes and after 24h from forming blocks. The durability index was calculated by using the following equation:

$$Durability\ index = \frac{Mass\ of\ sound\ block\ after\ tumbling}{Mass\ of\ block\ before\ tumbling} x\, 100,\% \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Stiffness of feed blocks:

Stiffness reflects the degree of binding. It was measured as the maximum force (Newton) recorded while the dry feed block was broken by a portable stiffness tester (Model, 174866-Kiyo-Seisakusho, L.T.D, Japan).

Productivity:

The productivity of formation equipments was determined with the average mass (or number) of the feed blocks and the calculated densification time.

Cost:

- Fixed costs:

a- Depreciation:

Declining balance method was used to determine the depreciation *(Hunt, 1983)*. In this method the depreciation value is different for every year of the machines life (hydraulic press and molds combination). Depreciation value was determined by using the following equation:

$$D = V_n - V_{n+1}, LE / Yr \quad \text{……………………………………………………}(4)$$

$$V_n = P\left(\frac{L - X}{L}\right)^n, LE / Yr \quad \text{……………………………………………......}(5)$$

$$V_{n+1} = P\left(\frac{L - X}{L}\right)^{n+1}, LE / Yr \quad \text{……………………………………...………}(6)$$

Where:

D	value of depreciation charged for year, (*n+1*);
P	purchase price, LE ;
L	time between buying and purchasing, Yr ;
n	number representing age of the machine in year at the beginning of year;
V	remaining value at any time and
X	ratio of depreciation rate for used machine (the maximum rate is 1.5).

b- Interest on investment, shelter taxes and insurance: They were estimated as 17.5% of the remaining value.

- Variable costs:

Variable costs include the cost of repairs and maintenance, hydraulic oil and labor. For machinery, repairs and maintenance is about 5.77% as a percent of purchase price.

Machinery unit cost: It calculated by using the following formula:

$$Machinery\,unit\,cost = \frac{Total\,cost}{Productivity}, LE / ton \quad \text{……………….…...………}(7)$$

RESULTS AND DISCUSSION

Bulk density of feed blocks:

Fig. 4 illustrates the effect of compression pressure, molasses content and rice straw moisture content for both cube and cuboid molds on bulk density of feed blocks. For cube mold, it can be observed that, the increase in compression pressure from 24.52 to 53.94MPa leads to increase the blocks bulk density from 260.48 to 346.67, from 315.24 to 401.56 and from 384.48 to 477.46kg/m^3 with molasses content of 4% and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase in compression pressure increased the blocks bulk density of cuboid mold from 254.03 to 320.23, from 298.79 to 395.11 and from 382.45 to 470.01kg/m^3 at the same above mentioned conditions, respectively. The same trend was obtained with other molasses content for cube and cuboid molds.

In the same manner, for cube mold, the increase of rice straw moisture content from 10.32 to 16.58% leads to increase the blocks bulk density from 260.48 to 384.48, from 281.86 to 433.76, from 302.58 to 454.18 and from 346.67 to 477.46kg/m^3 with molasses content of 4% and compression pressure of 24.52, 34.32, 44.13 and 53.94MPa, respectively. Also, the same increase of rice straw moisture content increased the blocks bulk density of

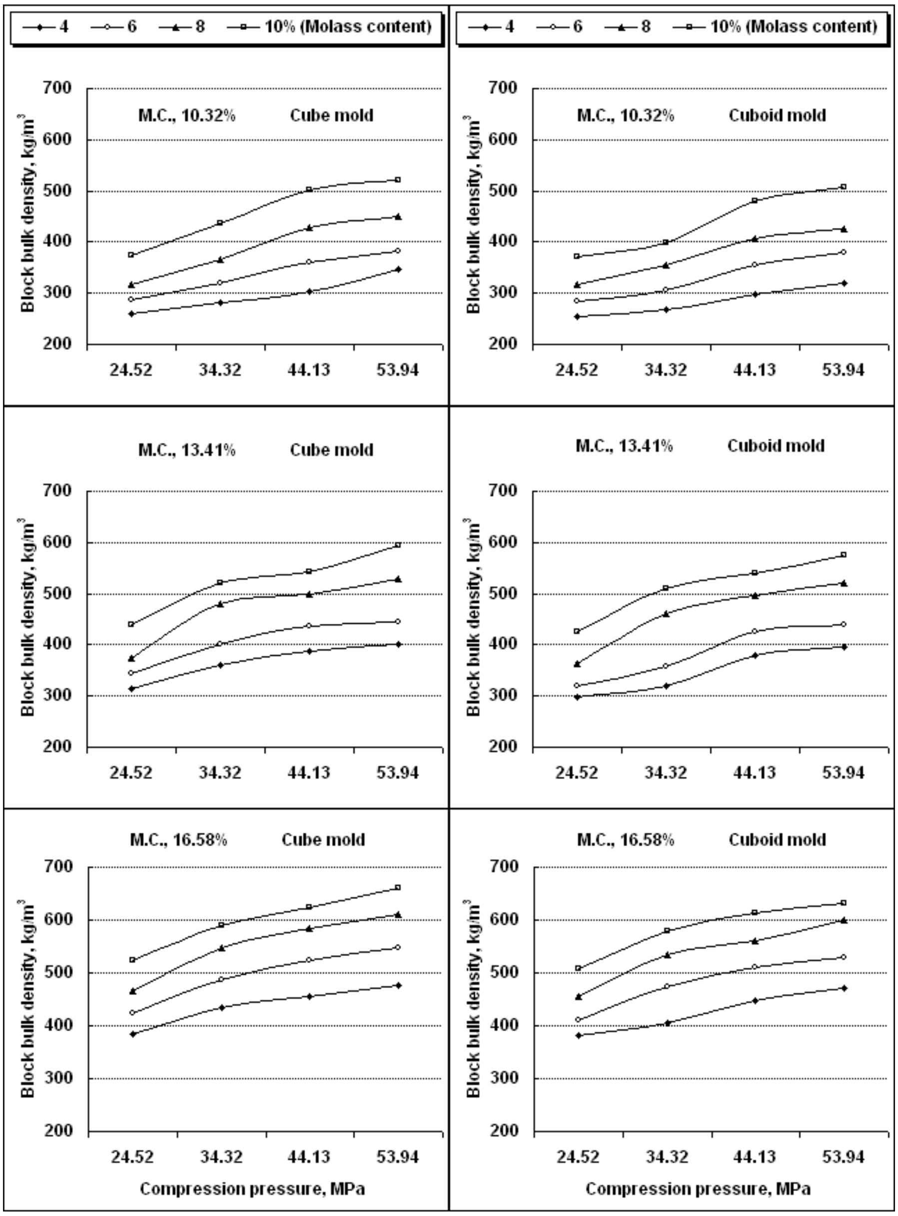


Fig. 4: Effect of compression pressure, molasses content and rice straw moisture content on block bulk density for cube and cuboid molds.

cuboid mold from 254.03 to 382.45, from 267.51 to 405.64, from 298.13 to 447.73 and from 320.23 to 470.01kg/m^3 at the same above mentioned conditions, respectively. The same results were obtained with other molasses content for cube and cuboid molds.

On the other hand, for cube mold, the increase of molasses content from 4 to 10% leads to increase the blocks bulk density from 260.48 to 373.52, from 315.24 to 440.42 and from 384.48 to 524.23kg/m^3 with compression pressure of 24.52MPa and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of molasses content increased the blocks bulk density of cuboid mold from 254.03 to 371.51, from 298.79 to 426.46 and from 382.45 to 508.88kg/m^3 at the same above mentioned conditions, respectively. The same trend was obtained with other compression pressure for cube and cuboid molds.

Briefly, it was noticed that the highest values of blocks bulk density of cube and cuboid molds were found to be 659.87 and 632.04kg/m^3, respectively, at compression pressure of 53.94MPa, molasses content of 10% and rice straw moisture content of 16.58%. Comparing the highest values of blocks bulk density for cube and cuboid molds, the results showed that, the value of block bulk density for cube mold was higher than that of cuboid mold by 4.4% at the same above mentioned conditions. In the opposite side, the lowest values of blocks bulk density of cube and cuboid molds were reached 260.48 and 254.03kg/m^3, respectively, at compression pressure of 24.52MPa, molasses content of 4% and rice straw moisture content of 10.32%. Comparing the lowest values of blocks bulk density for cube and cuboid molds, the data showed that, the value of block bulk density for cube mold was higher than that of cuboid mold by 2.5% at the same above mentioned conditions.

Eventually, for both cube and cuboid molds, the increase in compressibility of rice straw with increasing molasses and moisture contents has been attributed to the increase in cohesion and adhesion force between the compressed material due to increased formation of liquid bridges between the particles, also rice straw become softer and therefore deform more when they adsorb moisture. In addition, more of the void space is expelled when pressure is increased, hence the increase in compressibility. The results indicated that, the cube mold was found to be the most appropriate for high stability compressed blocks, this may be due to pressure distribution of cube mould on cross-sectional area was better than cuboid mould.

Densification degree of feed blocks:

The influences of compression pressure, molasses content and rice straw moisture content for both cube and cuboid molds on densification degree of feed blocks are shown in Fig. 5. General trend was observed where, the blocks densification degree increased by increasing the compression pressure at constant molasses content and rice straw moisture content. For cube mold, it can be observed that, the increase of compression pressure from 24.52 to 53.94MPa leads to increase the blocks densification degree from 50.56 to 100.38, from 82.21 to 132.10 and from 122.23 to 175.97% with molasses content of 4% and rice straw moisture content of

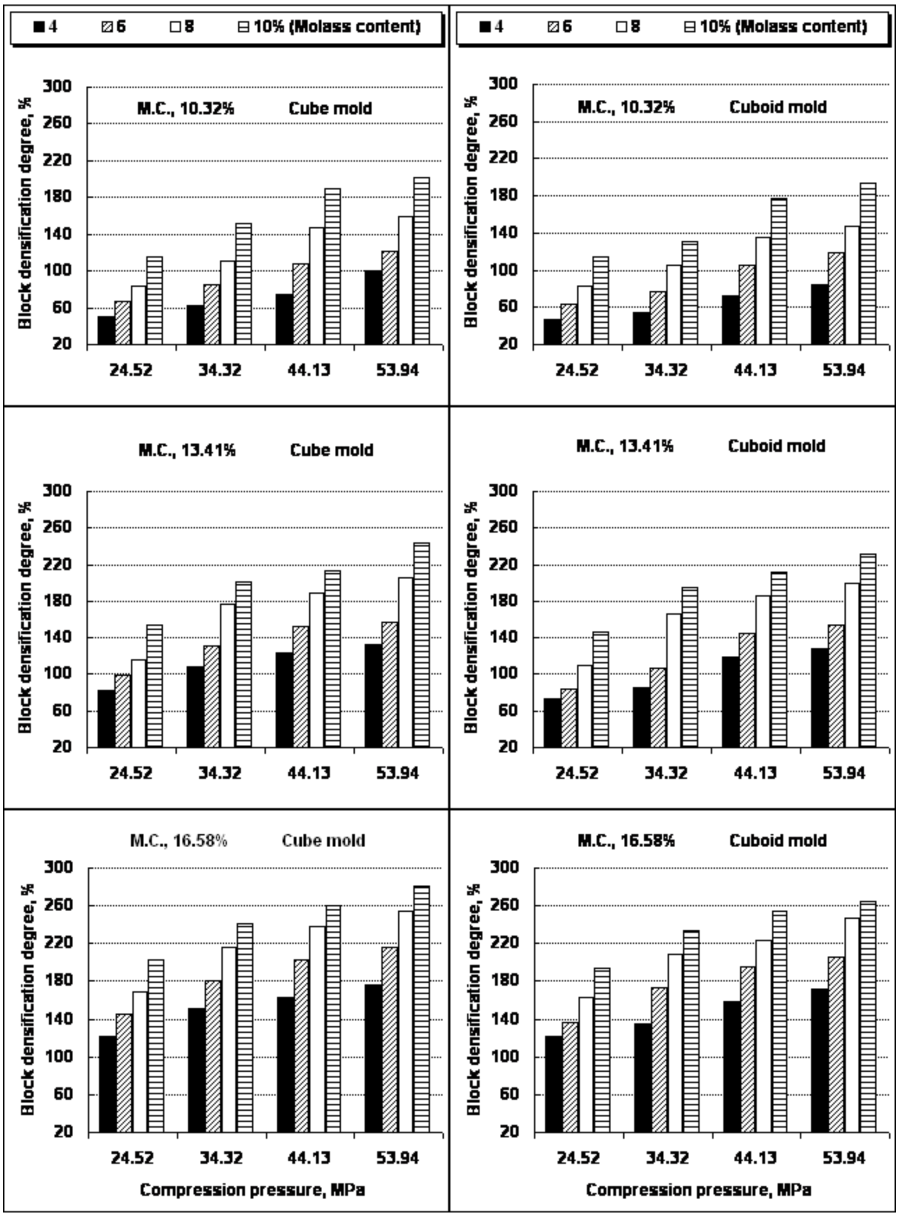


Fig. 5: Effect of compression pressure, molasses content and rice straw moisture content on block densification degree for cube and cuboid molds.

10.32, 13.41 and 16.58%, respectively. Also, the same increase of compression pressure increased the blocks densification degree of cuboid mold from 46.83 to 85.09, from 72.70 to 128.37 and from 121.06 to 171.67% at the same above mentioned conditions, respectively. The same trend was obtained with other molasses content for cube and cuboid molds.

For cube mold, the increase of rice straw moisture content from 10.32 to 16.58% leads to increase the blocks densification degree from 50.56 to 122.23, from 62.92 to 150.71, from 74.89 to 162.52 and from 100.38 to 175.97% with molasses content of 4% and compression pressure of 24.52, 34.32, 44.13 and 53.94MPa, respectively. Also, the same increase of rice straw moisture content increased the blocks densification degree of cuboid mold from 46.83 to 121.06, from 54.62 to 134.46, from 72.32 to 158.79 and from 85.09 to 171.67% at the same above mentioned conditions, respectively. The same results were obtained with other molasses content for cube and cuboid molds.

In the same manner, for cube mold, the increase of molasses content from 4 to 10% leads to increase the blocks densification degree from 50.56 to 115.90, from 82.21 to 154.56 and from 122.23 to 203.01% with compression pressure of 24.52MPa and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of molasses content increased the blocks densification degree of cuboid mold from 46.83 to 114.73, from 72.70 to 146.49 and from 121.06 to 194.13% at the same above mentioned conditions, respectively.

In general, it was noticed that the highest values of blocks densification degree of cube and cuboid molds were found to be 281.41 and 265.32%, respectively, at compression pressure of 53.94MPa, molasses content of 10% and rice straw moisture content of 16.58%. Comparing the highest values of blocks densification degree for cube and cuboid molds, the results showed that, the value of block densification degree for cube mold was higher than that of cuboid mold by 6.1% at the same above mentioned conditions. On the other hand, the lowest values of blocks densification degree of cube and cuboid molds were reached 50.56 and 46.83%, respectively, at compression pressure of 24.52MPa, molasses content of 4% and rice straw moisture content of 10.32%. Comparing the lowest values of blocks densification degree for cube and cuboid molds, the data showed that, the value of block densification degree for cube mold was higher than that of cuboid mold by 8% at the same above mentioned conditions.

Resiliency of feed blocks:

Data presented in Fig. 6 illustrates the impact of compression pressure, molasses content and rice straw moisture content for both cube and cuboid molds on feed blocks resiliency. For cube mold, it can be observed that, the increase of compression pressure from 24.52 to 53.94MPa leads to decrease the blocks resiliency from 25.35 to 21.41, from 23.88 to 19.94 and from 19.45 to 15.48% with molasses content of 4% and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of compression pressure decreased the blocks resiliency of cuboid mold from 28.04 to 23.53, from 26.12 to 22.26 and from 22.20 to 17.34% at

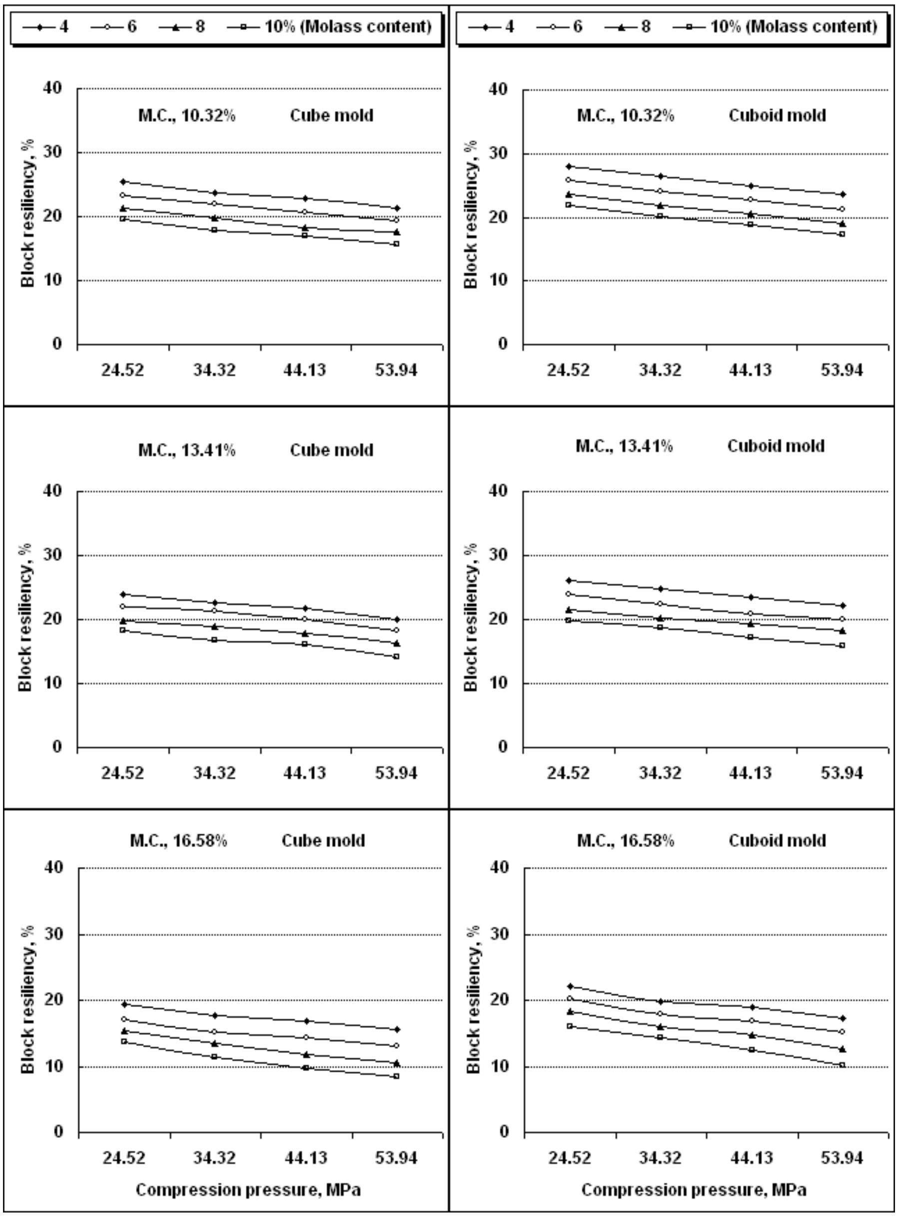


Fig. 6: Effect of compression pressure, molasses content and rice straw moisture content on block resiliency for cube and cuboid molds.

the same above mentioned conditions, respectively. The same trend was obtained with other molasses content for cube and cuboid molds.

In the same manner, for cube mold, the increase of rice straw moisture content from 10.32 to 16.58% leads to decrease the blocks resiliency from 25.35 to 19.45, from 23.65 to 17.72, from 22.75 to 16.82 and from 21.41 to 15.48% with molasses content of 4% and compression pressure of 24.52, 34.32, 44.13 and 53.94MPa, respectively. Also, the same increase of rice straw moisture content decreased the blocks resiliency of cuboid mold from 28.04 to 22.20, from 26.39 to 19.79, from 24.98 to 18.89 and from 23.53 to 17.34% at the same above mentioned conditions, respectively. The same results were obtained with other molasses content for cube and cuboid molds.

On the other hand, for cube mold, the increase of molasses content from 4 to 10% leads to decrease the blocks resiliency from 25.35 to 19.57, from 23.88 to 18.17 and from 19.45 to 13.64% with compression pressure of 24.52MPa and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of molasses content decreased the blocks resiliency of cuboid mold from 28.04 to 21.86, from 26.12 to 19.73 and from 22.20 to 16.09% at the same above mentioned conditions, respectively. The same trend was obtained with other compression pressure for cube and cuboid molds.

Generally, it was noticed that the lowest values of blocks resiliency of cube and cuboid molds were found to be 8.35 and 10.03%, respectively, at compression pressure of 53.94MPa, molasses content of 10% and rice straw moisture content of 16.58%. Comparing the lowest values of blocks resiliency for cube and cuboid molds, the results showed that, the value of block resiliency for cube mold was less than that of cuboid mold by 16.7% at the same above mentioned conditions. In the opposite side, the highest values of blocks resiliency of cube and cuboid molds were reached 25.35 and 28.04%, respectively, at compression pressure of 24.52MPa, molasses content of 4% and rice straw moisture content of 10.32%. Comparing the highest values of blocks resiliency for cube and cuboid molds, the data showed that, the value of block resiliency for cube mold was less than that of cuboid mold by 9.6% at the same above mentioned conditions.

Durability of feed blocks:

Fig. 7 explains the blocks durability as affected by compression pressure for both cube and cuboid molds at different levels of molasses content and moisture content of rice straw. For cube mold, it is conceivable that, the increase of compression pressure from 24.52 to 53.94MPa tends to increase the blocks durability from 93.02 to 96.68, from 92.07 to 94.85 and from 89.73 to 93.28% with molasses content of 4% and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of compression pressure increased the blocks durability of cuboid mold from 91.03 to 93.98, from 88.82 to 92.87 and from 87.74 to 90.72% at the same above mentioned conditions, respectively. The same trend was obtained with other molasses content for cube and cuboid molds.

From the previous data it is evident that, for cube mold, the increase of rice straw moisture content from 10.32 to 16.58% tends to decrease the

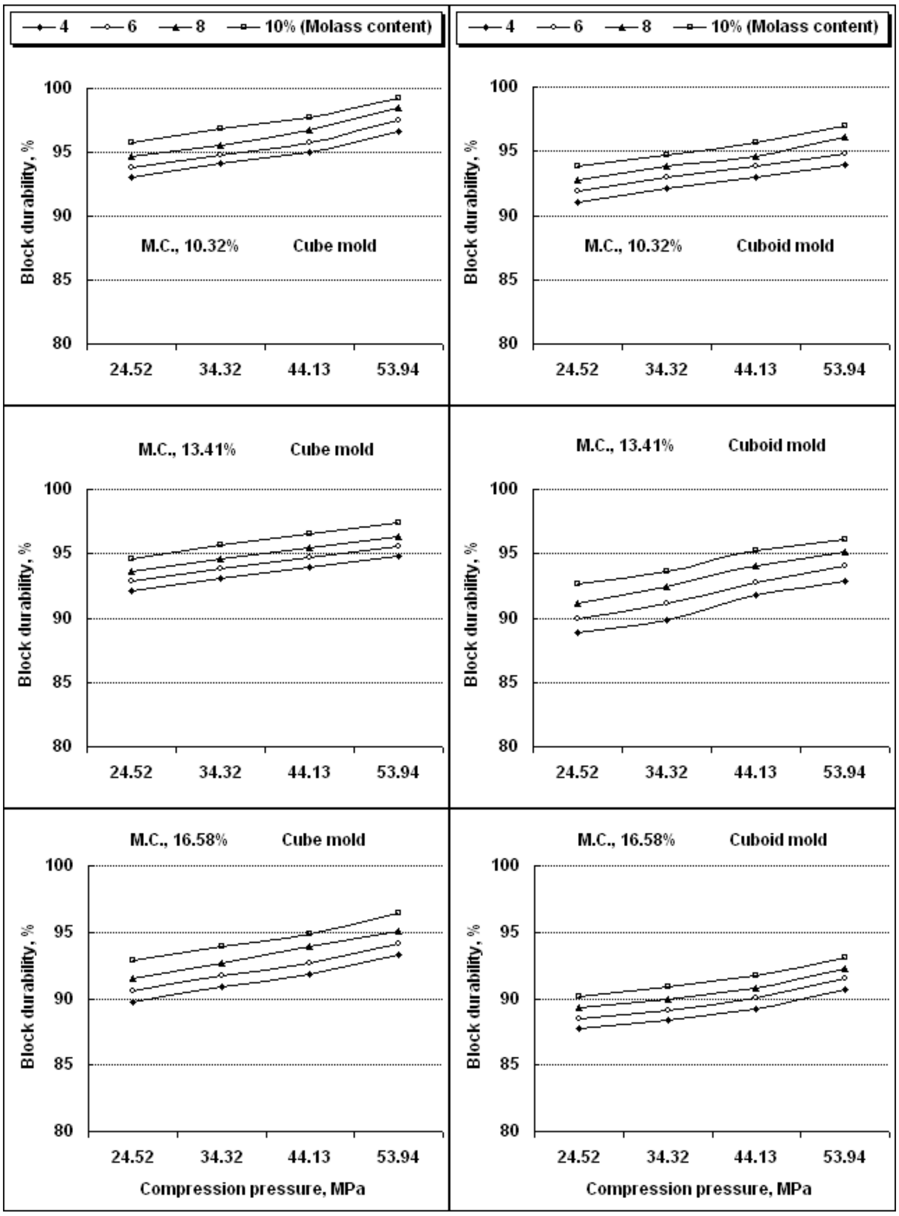


Fig. 7: Effect of compression pressure, molasses content and rice straw moisture content on block durability for cube and cuboid molds.

blocks durability from 93.02 to 89.73, from 94.08 to 90.86, from 94.99 to 91.81 and from 96.68 to 93.28% with molasses content of 4% and compression pressure of 24.52, 34.32, 44.13 and 53.94MPa, respectively. Also, the same increase of rice straw moisture content decreased the blocks durability of cuboid mold from 91.03 to 87.74, from 92.08 to 88.34, from 92.99 to 89.23 and from 93.98 to 90.72% at the same above mentioned conditions, respectively. The same results were obtained with other molasses content for cube and cuboid molds.

Moreover, for cube mold, the increase of molasses content from 4 to 10% tends to increase the blocks durability from 93.02 to 95.79, from 92.07 to 94.59 and from 89.73 to 92.84% with compression pressure of 24.52MPa and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of molasses content increased the blocks durability of cuboid mold from 91.03 to 93.79, from 88.82 to 92.61 and from 87.74 to 90.19% at the same above mentioned conditions, respectively. The same trend was obtained with other compression pressure for cube and cuboid molds.

Briefly, it was observed that, the highest values of blocks durability of cube and cuboid molds were found to be 99.27 and 96.92%, respectively, at compression pressure of 53.94MPa, molasses content of 10% and rice straw moisture content of 10.32%. Comparing the highest values of blocks durability for cube and cuboid molds, the results showed that, the value of block durability for cube mold was higher than that of cuboid mold by 2.4% at the same above mentioned conditions. In the opposite side, the lowest values of blocks durability of cube and cuboid molds were reached 89.73 and 87.74, respectively, at compression pressure of 24.52MPa, molasses content of 4% and rice straw moisture content of 16.58%. Comparing the lowest values of blocks durability for cube and cuboid molds, the data showed that, the value of block durability for cube mold was higher than that of cuboid mold by 2.3% at the same above mentioned conditions.

Stiffness of feed blocks:

Data presented in Fig. 8 illustrates the effect of compression pressure, molasses content and rice straw moisture content for both cube and cuboid molds on feed blocks stiffness. For cube mold, it can be observed that, the increase of compression pressure from 24.52 to 53.94MPa tends to increase the blocks stiffness from 371.24 to 380.32, from 365.42 to 374.79 and from 358.46 to 367.92N with molasses content of 4% and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of compression pressure increased the blocks stiffness of cuboid mold from 367.41 to 375.63, from 360.93 to 368.45 and from 354.85 to 362.96N at the same above mentioned conditions, respectively. The same trend was obtained with other molasses content for cube and cuboid molds.

From the previous data it is evident that, for cube mold, the increase of rice straw moisture content from 10.32 to 16.58% tends to decrease the blocks stiffness from 371.24 to 358.46, from 374.19 to 361.62, from 377.81 to 364.75 and from 380.32 to 367.92N with molasses content of 4% and compression pressure of 24.52, 34.32, 44.13 and 53.94MPa, respectively. Also, the same increase of rice straw moisture content decreased the blocks

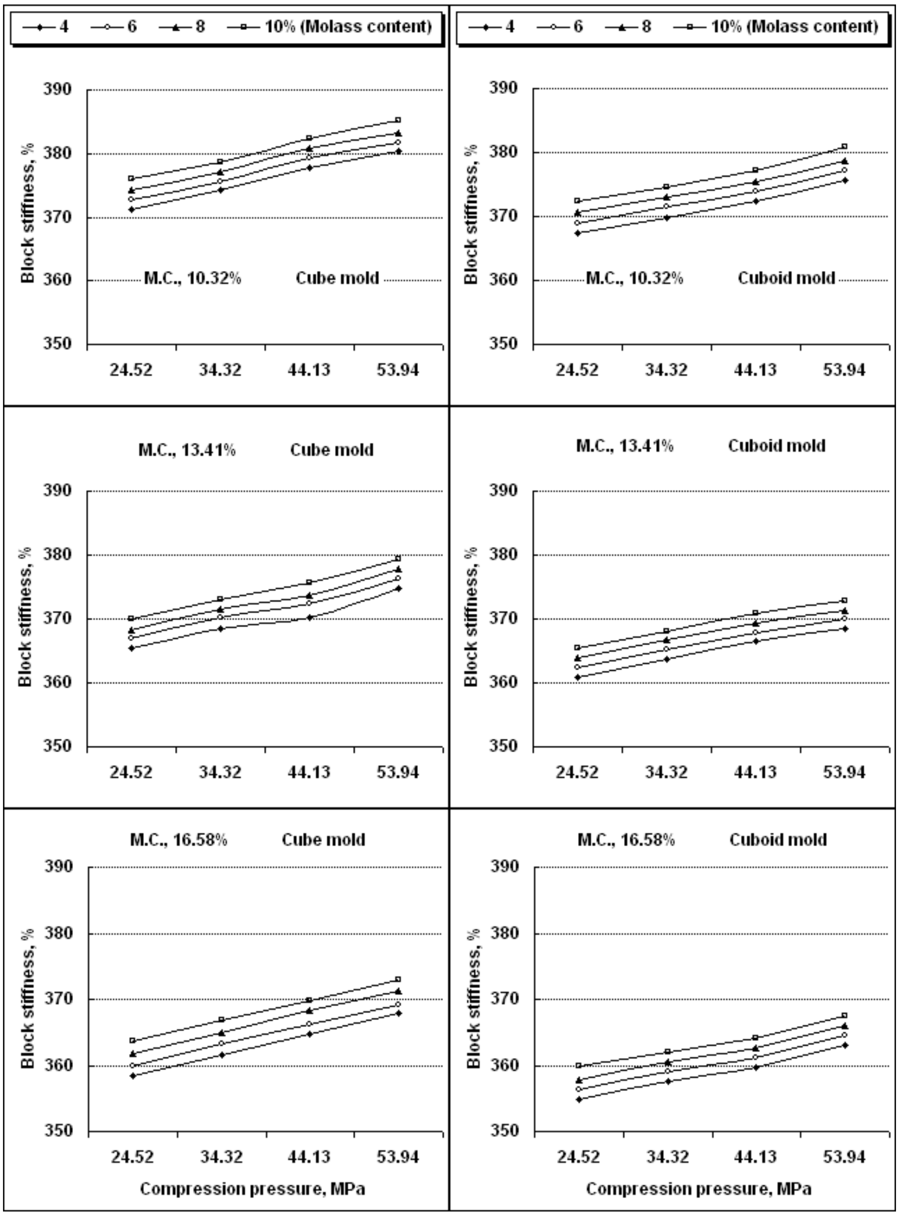


Fig. 8: Effect of compression pressure, molasses content and rice straw moisture content on block stiffness for cube and cuboid molds.

stiffness of cuboid mold from 367.41 to 354.85, from 369.85 to 357.64, from 372.34 to 359.63 and from 375.63 to 362.96N at the same above mentioned conditions, respectively. The same results were obtained with other molasses content for cube and cuboid molds.

On the other hand, for cube mold, the increase of molasses content from 4 to 10% tends to increase the blocks stiffness from 371.24 to 375.95, from 365.42 to 369.94 and from 358.46 to 363.70N with compression pressure of 24.52MPa and rice straw moisture content of 10.32, 13.41 and 16.58%, respectively. Also, the same increase of molasses content increased the blocks stiffness of cuboid mold from 367.41 to 372.35, from 360.93 to 365.45 and from 354.85 to 359.86N at the same above mentioned conditions, respectively. The same trend was obtained with other compression pressure for cube and cuboid molds.

Generally, it was observed that, the highest values of blocks stiffness of cube and cuboid molds were found to be 385.22 and 380.86N, respectively, at compression pressure of 53.94MPa, molasses content of 10% and rice straw moisture content of 10.32%. Comparing the highest values of blocks stiffness for cube and cuboid molds, the results showed that, the value of block stiffness for cube mold was higher than that of cuboid mold by 1.1% at the same above mentioned conditions. In the opposite side, the lowest values of blocks stiffness of cube and cuboid molds were reached 358.46 and 354.85N, respectively, at compression pressure of 24.52MPa, molasses content of 4% and rice straw moisture content of 16.58%. Comparing the lowest values of blocks stiffness for cube and cuboid molds, the data showed that, the value of block stiffness for cube mold was higher than that of cuboid mold by 1% at the same above mentioned conditions.

Productivity and Machinery unit cost:

For all operating conditions, the time to produce four blocks was about 0.0666h at one time, and the average mass of the feed block was about 0.75kg. So, the average productivity of the investigated feed block formation equipments was 60 feed block/h (45kg/h). The feed blocks production cost using the hydraulic press with the molds combination are listed in Table 1. As shown in the table, the estimated unit cost of the feed blocks using the formation equipments was 8.144LE/h, whilst the production cost per kg of raw material was 0.18097LE.

Table 1: Cost estimation for the hydraulic press with molds combination.

Assumptions:	
Price of the hydraulic press and molds combination, LE	4000
Time to produce four blocks, h	0.0666
Number of the feed blocks per hour	60
Average mass of feed block, kg	0.75
Operation hours, h/Yr	2000
Total fixed cost, LE/h	0.5079
Depreciation cost, LE/h	0.2550
Interest, taxes, insurance and shelter cost, LE/h	0.2529
Total Variable cost, LE/h	7.6365
Repair and maintenance cost, LE/h	0.0115
hydraulic oil cost, LE/h	0.1250
Labor cost, LE/h	7.5
Machinery unit cost:	
LE/h	8.144
LE/kg	0.18097
LE/ton	180.97

CONCLUSIONS

The following conclusions were drawn from this study:

- A combination of compression pressure of 53.94MPa, molasses content of 10% and 16.58% moisture content of rice straw was optimum. Under the optimum settings of the variables, for cube and cuboid molds, the feed blocks produced had a bulk density of 659.87 and 632.04kg/m^3, densification degree of 281.41 and 265.32% and resiliency of 8.35 and 10.03%, respectively.
- For cube and cuboid molds, the highest values of blocks durability were found to be 99.27 and 96.92%, respectively, at 10.32% moisture content of rice straw, 53.94MPa compression pressure and 10% molasses content, and also the highest values of blocks stiffness were 385.22 and 380.86N, respectively at the same previous conditions.
- Comparing between the two geometrical shapes of mold, the cube mold was found to be the most appropriate for high stability compressed blocks.
- The average productivity of the investigated feed block formation equipments was 60 feed block/h, while the machinery unit cost was about 8.144LE/h.

REFERENCES

AboSalim, I. A. and M. M. Bendary (2005). Forage supplies in Egypt-resources-maximizing its utilization. Proc. 2nd Conf. Anim. Prod. Res. Inst., Sakha 27-29, Sep., 2005: 57-67.

AbouElmaged, A. E.; Y. M. ElHadidi and N. Kh. Ismail (2003). Engineering studies on the compressing process of untraditional poultry feed. The 11th Annual Conference of the Misr Society of Ag. Eng., 15-16 Oct., 2003: 508-524.

Al-Widyan, M. I.; H. F. Al-Jalil; M. M. Abu-Zreig and N. H. Abu-Hamdeh (2002). Physical durability and stability of olive cake briquettes. Canadian Biosystems Eng., 44: 3-41.

ASAE, (1998). American society of agricultural engineers, Standards-Engineering practices, and Data, ASAE standard book.

Ferrero, A; J. Horabik and M. Molenda (1990). Density-pressure relationship in compaction of straw. Canadian J. of Ag. Eng., 33:107-111.

Ghanem, G. H. A.; M. M. Bendray; H. M. A. Gaafar; M. I. Abou Youssef and A. E. Deraz (2005). Utilization of rice straw for feeding ruminants: (Productive performance of lactating cows fed berseem and different from of rice straw). Animal Production Research institute 2nd Conference and Regional Symposium on Buffalo Production, 27-29 Sep., Sakha, Kafr El-Sheikh, Egypt, 155.

Ghorpade, S. S. and A. P. Moule (2006). Performance evaluation of deoiled cashew shell waste for fuel properties in bri-quetted form. B. Tech. Thesis (Unpub.),Dapoli, 15.

Hunt, D. (1983). Farm power and machinery management. 8th Ed. Iowa State Univ. Press, Ames., U.S.A., 59-71.

Jha, S. K.; A. K. Singh and A. Kumar (2008). Physical characteristics of compressed cotton stalks. Biosystems Eng., 99: 205-210.

Kaliyan, N. and R. Vance Morey (2009). Factors affecting strength and durability of densified biomass products. biomass and bioenergy, 33: 337-359.

Khan, B. B.; A. Iqbal and M. I. Mustafa (2003). Sheep and goat production. TM Graphics, Al-Rehman plaza, St. 6, Munshi Mohallah, Aminpur Bazar, Faisalabad, Pakistan., 232-233.

Ndiema, C. K. W; P. N. Manga and C. R. Ruttoh (2002). Influence of die pressure on relaxation characteristics of briquetted biomass. Energy Conversion Management, 43: 2157-2161.

O'Dogherty, M. J. and J. A. Wheeler (1984). Compression of straw to high densities in closed cylindrical dies. J. of Ag. Eng. Res., 29: 61-72.

Payne, J. D. (2006). Troubleshooting the pelleting process. Feed technology. American soybean association international marketing southeast Asia. 17-23.

Sarwar, M.; M. A. Khan and Z. Iqbal (2002). Feed resources for livestock in Pakistan. Int. J. Ag. Biol., 4: 186-192.

Singh, A. K.; J. S. Panwar; A. Kumar; S. K. Jha and A. Pandeya (2002). Management of animal feed materials through densification. J. of Ag. Eng., 39: 9-15.

Singh, A. K.; S. K. Jha; J. S. Panwar and A. Pandeya (2005). Studies on compaction of crop residues. IE(I) J. Ag., 86: 54-57.

Tumuluru, J. S.; C. T. Wright; K. L. Kenney and J. R. Hess (2010). A technical review on biomass processing: densification, preprocessing, modeling and optimization. ASABE Annual International Meeting (1009401)., 2950 Niles Road, St. Joseph, MI 49085-9659, USA.

تطوير وتقييم أداء مكبس هيدروليكي لتشكيل قوالب علف الحيوان

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يعد قش الأرز من مخلفات المحاصيل الحقلية التي لها كثافة ظاهرية منخفضة والتي يصعب معها عمليات النقل والتداول والتخزين مما يضطرالمزارعين إلى حرقه ويؤدى هذا بدوره إلى مشاكل بيئية واسعة. ويعد استخدام قش الأرز في صورة قوالب أو بلوكات علف لتغذية الحيوان مضافا إليها النسب الصحيحة من مكملات العناصر الغذائية التي يحتاجها الحيوان أحد التقنيات المبتكرة للاستفادة من قش الأرز لتقليل الفجوة العلفية كماً ونوعاً في مصر مما ينتج عنة خفض في تكاليف تغذية الحيوان وزيادة العائد للمربى. لذلك استهدفت الدراسة تطوير وتقييم أداء مكبس هيدروليكي لتشكيل قوالب علف الحيوان من قش الأرز المقطع مضافا إليه مولاس قصب السكر كمادة رابطة وتم تقييم أداء نموذج الكبس المطور تحت تأثير أربع مستويات مختلفة من الضغوط وهى (٢٤.٥٢، ٣٤.٣٢، ٤٤.١٣ و٥٣.٩٤ميجاباسكال) وشكلين هندسيين للقالب وهما (المكعب ومتوازي المستطيلات) وأربع مستويات مختلفة من محتوى المولاس وهى (٤، ٦، ٨ و١٠%) وثلاث مستويات من المحتوى الرطوبى لقش الأرز وهى (١٠.٣٢، ١٣.٤١ و١٦.٥٨% على أساس رطب) وتم دراسة تأثير تلك العوامل على الخواص الهامة لبلوكات العلف المضغوطة مثل الكثافة الظاهرية، درجة التكثيف، المرونة، المتانة والصلابة. كما تم تقدير الإنتاجية وتكاليف التشغيل للمكبس موضوع البحث.

أظهرت النتائج أن ظروف التشغيل ٥٣.٤٩ميجاباسكال لضغط المكبس و١٠% لمحتوى المولاس و١٦.٥٤% محتوى رطوبى لقش الأرز هي الأمثل لإنتاج بلوكات العلف باستخدام قالبي التشكيل المكعب ومتوازي المستطيلات حيث أعطت كثافة ظاهرية ٦٥٩.٨٧ و٦٣٢.٠٤كجم/متر مكعب ودرجة تكثيف ٢٨١.٤١ و٢٦٥.٣٢% ومرونة ٨.٣٥ و١٠.٠٣% على الترتيب. وبينت النتائج أيضا أن أعلى نسبة متانة لبلوكات العلف هي ٩٩.٢٧ و٩٦.٩٢% وأقصى صلابة هي ٣٨٥.٢٢ و٣٨٠.٨٦نيوتن لقالبي التشكيل المكعب ومتوازي المستطيلات على الترتيب وذلك عند ١٠.٣٢% محتوى رطوبى لقش الأرز ونفس ظروف التشغيل لضغط المكبس ومحتوى المولاس المذكور سابقا. كما أوضحت النتائج أن القالب المكعب أكثر ثبات لإنتاج بلوكات العلف عن متوازي المستطيلات. وبلغ متوسط الإنتاجية ٦٠ بلوك علف/ساعة (٤٥كجم/ساعة) وتكاليف التشغيل لنموذج الكبس المطور ١٨٠.٩٧جنية/طن علف مكبوس عند ظروف التشغيل المختلفة.