Manufacture and Evaluation of an Alternative Feeds Production Machine

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ABSTRACT

The main objectives of this research are to fabricate a machine for producing a special feed with an easy operating system, that is suitable for small breeders, with low operating costs and high productivity, as well as substitution of barley grains in the feed components by sprouted barley in order to reduce costs and to increase amount of green feed and percentage of protein. The fabricated machine consisted of four main units; power and power transmission unit; chopping unit; mixing unit and pelletizing unit. Experiments were conducted to test the fabricated machine under three levels of moisture content for sprouted barley (70.09, 79.71 and 81.35 %); three different die holes’ diameters (4, 6 and 8 mm); and three mixing times (10, 15 and 20 minutes). The results indicated that the mean bulk density was 443.3 Kg/m³. The shear stress was 0.68 N. The mean vertical and horizontal rupture forces were 3.04 and 4.11 N, respectively. The mean machine productivity was 31.78 kg/hr. The mean mixing efficiency was 81.14 %. The mean pelleting efficiency was 75.75 %. The mean specific energy requirement 74.47 Kw.hr/Mg. The chemical analysis of produced pellets indicated that ash content was 9.1 %, protein was 21.26 % and fat was 1.98 %, so it is recommended to use the fabricated machine for producing alternative feed.

**Keywords:** sprouted barley, chopping, mixing, pelletizing, alternative feeds.

INTRODUCTION

Feed manufacturers usually select ingredients that are the least cost but still meet the desired nutritive properties as sprouted barley, which consider a good source of protein, carbohydrate, minerals and vitamins. Feed availability, new feed ingredients and new feeding practices have played important roles in the concentration of animal food production operations (Church, 1991; Naik and Singh, 2013) said that in the hydroponic system, the green fodder is harvested in about seven days. The reviewed researches are divided into some topics. First topic is focused on the use of sprouted barley in feed ingredients, as a small amount of barley grains yields about 4 times from the sprouted barley with little cost and effort. Secondly, the benefits of feed cutting are examined. More clearly, quality of sprouted barley is improved by physical treatments includes chopping, shredding, grinding and pelleting (Matthers and Otchere, 2012). Also, knife mills or choppers work successfully for shredding forages under various crops and machine conditions. Disc mills produce very small particles if input feed is provided by knife mills or hammer mills (Hoque et al., 2007). The range of cutting crop (1-3 cm) is suitable for small animals while the range of 3-5 cm is suitable for large animals (Church, 1991). However, using sprouted barley as alternative feed can solve serious problems of animal feeding shortage in Egypt. Chopping material in pieces less than 3 cm improves its efficiency when used in feeding livestock (El-Berry et al., 2001). Last topic concerns the development of feed cutting devices. The results for an improved designed cutting machine for rice straw and maize stalks indicated that the maximum percentages (87.80 and 92%) in cutting length of less than 5 cm were obtained for rice straw and corn stalks residues, respectively, at cutting speed of 10.09 m/s, feeding rate of 0.771 ton/h and knife clearance of 1.5 mm while the energy consumed was 6.36 and 6.17 kWh/ton. (El-Iraqi and El-Khawaga, 2003; Ikubann et al. 2019) reported that there are various types and forms of pelleting equipments. They are varying from their dimensions, shapes, process, operation (manual or automatic), capability and function. The processes of this machines are: grinding, mixing and extrusion (Regupathi et al., 2019). Balami et al. (2013) designed, evaluated and tested an animal feed mixing machine using a feed portion divided into three equal steps. The machine was tested for four mixing period of 10, 15 and 20 minutes. The mixing efficiency was 95.16 %, when the mixing time was 10 minutes. Leman et al. (2017) suggested a continuous mixer to increase mixing efficiency with a shorter mixing process time. Ojomo et al. (2010) illustrated that as the speed of the machine increases, the efficiency of the machine increases. Orisaleye et al. (2009) mentioned that the pelleting die is necessary to limit the flow and supply of feed material and the pellet’s cylindrical form. Abubakre et al. (2014) designed motorized mechanical feed pelletizer machine and reported that the machine efficiency was increased by increasing die size. Orisaleye et al. (2009) designed a livestock feed machine. The density of pellets was varied from 0.7 to 1 g/cm³. The bulk density of the pellets determines the required storage space in the feed manufacturing units and also during transport. The size, shape and filling method influence the bulk density of the pellets (Ighodalo et al. 2020). Khat et al. (2014) showed that physical and mechanical properties of fish feed pellets such as bulk density, durability, moisture content and crushing load were varied from 267.11 to 711.35 Kg/cm³, 70.66 to 92.62 %, 16.68 to 17.82% and 6.13 to 33.28 N, respectively. Orisaleye et al. (2009) cleared that average
specific energy consumption when using 750 cm³ of starch binder was 0.69 kW·h/Kg, while it was 0.93 kW·h/Kg when water was used as preconditioner.

Thus, the main objectives of the current research are to investigate the production of alternative feeds using newly developed mixing and making machine and to minimize the operating cost of produced feeds.

**MATERIALS AND METHODS**

Experiments were carried out at faculty of Agriculture – Damietta University. The machine was designed for chopping, mixing and pelletizing raw materials to produce alternative fodder.

**Raw materials**

Barley (Giza 132) was grown in trays (30 x 70 cm) for about 7 to 9 days after being purified and sifted. The composition percentages of the experimental rabbit diets used for rabbit pelletizing machine is shown in Table 1.

<table>
<thead>
<tr>
<th>S/N</th>
<th>FEED INGREDIENTS</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wheat bran</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Sprouted barley</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Soybean meal</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>Yellow maize</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Dried alfalfa</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>Limestone</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Sodium chloride</td>
<td>0.3</td>
</tr>
<tr>
<td>8</td>
<td>Dicalciamphosphate</td>
<td>1.25</td>
</tr>
<tr>
<td>9</td>
<td>Anti-toxin</td>
<td>0.1</td>
</tr>
<tr>
<td>10</td>
<td>Anti-cococidia</td>
<td>0.05</td>
</tr>
<tr>
<td>11</td>
<td>Molasses</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Premix</td>
<td>0.3</td>
</tr>
</tbody>
</table>

The new fabricated machine

The new fabricated machine consists of the following parts as follows:

1) **Power source**: An electric motor [3 Hp (2.2 KW), 8.7 A, 220/380 V and 1400 rpm] was used. Power is transmitted from a pulley (70 mm diameter) on the main motor shaft to a pulley (80 mm diameter) on the cutting blades shaft, to a pulley (200 mm diameter) on mixing levers shaft, to a pulley (190 mm diameter) on the feeding belt shaft and to a pulley (190 mm diameter) on pelleting unit shaft by mains of five V belts (Figure 1).

2) **Chassis**: The chassis [0.75x0.38x0.17 m lengthx widthx height] is made from L shape iron (6 cm) which welded and manufactured locally to stand tracking on its own four wheels 12 cm diameter. The fabricated machine has dimensions of 1.42x0.55x1.2 m lengthx widthx height as shown in the schematic drawing Figure 2.

3) **The cutting unit**: As shown in Figure 3, an inside cutter drum have the cutting action for the transmitted feed to the unit. It is provided with an inlet feeding belt (1200 mm length and 250 mm width) with two edges. Four cutting blades (250 mm length and 60 mm width) were used for cutting sprouted barley at a speed of 1260 rpm (6.6 m/s) to produce cutting length of about 2.67 cm.

4) **Feeding hooper**: The feeding hopper was made from steel sheet (2 mm thickness, 240 mm height, 180x180 mm upper opening and 10x10 mm lower opening). The feeding hopper provided with a gate at the bottom to control the amount of feeding material. The maximum capacity of the feeding hopper was 20 Kg.
Figure 4. Mixing unit

6) The pelletizing unit: The pelletizing unit consists of a screw conveyor (230 mm length, 100mm in diameter and pitch of 40 mm). Rotational speed of screw conveyor was 263.18 rpm (2.62 m/s). A forming die was assembled in die house by bolts 10 mm diameters. The outer diameter of all dies were 100 mm and 10 mm thickness. There are three types of die, die 4 mm hole diameter which has 57 holes in its surface, die 6 mm hole diameter which has 48 holes in its surface and die 8 mm hole diameter which has 33 holes in its surface as shown in the Figure 5. The actual final side and front views of the fabricated machine are presented in Figure 6 and Figure 7.

Figure 5. Die diameter 4, 6 and 8 mm.

Instruments

UNIT-T UT371 Tachometers ranged from 10 – 99999 rpm was used for measuring speeds. To determine the mechanical properties of pellets, a proprietary tension/compression testing machine (Instron Universal Testing Machine/SMT-5) was used; which was equipped with a 500 kg compression load cell and an integrator (Saiedirad et al., 2008). The measurement accuracy was ± 0.001 N in force (Figure 8).

Figure 8. Universal material tester

The individual pellet was loaded between two parallel plates of the machine and compressed along with thickness until rupture occurred. This was denoted by a rupture point in the force – deformation curve. The rupture point is a point on
the force – deformation curve at which the loaded sample shows a visible or invisible failure in the form of breaks or cracks. This point is detected by a continuous decrease of the load in the force - deformation diagram. While the rupture point was detected, the loading was stopped. These tests were carried out at the loading rate of 5 mm/min for all moisture levels (ASAE, 2006). The mechanical behavior of rabbit feed was expressed in terms of shear force and ruptured force. Three replications were made for each test. An electrical balance sensitive scale with an accuracy of 0.01 gm. was used to measure the mass of the samples.

**Study of performance parameters**

All experiments were performed under the following variables:

- Three different moisture contents of sprouted barley (70.09, 79.71 and 81.35%).
- Three die diameters (4, 6 and 8 mm).
- Three mixing duration times of (10, 15 and 20 min).

**Measurements**

To determine the optimum conditions for the machine under study, the following criteria were studied:

1) **Moisture content:** The moisture content (d.b., %) were determined by oven method. About five grams of samples were placed in a shallow aluminum dish and dried for 22 hours at 130°C. At the end of this time the constant mass showed that all moisture was driven off.

   \[ M.C_{d.b} = \frac{W_f - W_d}{W_d} \times 100 \]  
   \[ (1) \]

   **Where:**
   - \( M.C_{d.b} \) = Moisture content, dry basis, %.
   - \( W_f \) = Initial mass of sample, g.
   - \( W_d \) = Dried mass of sample, g.

2) **Bulk density:** It was determined according to ASAE (2003). Samples were taken to determine their mass and volume. The bulk density was calculated as the ratio of the bulk mass and the volume of the container.

   \[ \beta = \frac{m}{v}, \text{ kg/m}^3 \]  
   \[ (2) \]

   **Where:**
   - \( \beta \) : the bulk density of the material, kg/m³
   - \( m \) : mass of material in kg, and
   - \( v \) : volume of the container in m³

3) **The machine productivity:** The productivity of the pelleting machine was determined with the help of a digital stopwatch of 0.1-sec. accuracy and an electrical balance of (0.0001g) accuracy. Machine productivity (pelletizing capacity) (P, kg/hr) was calculated as follows (Regupathi et al. 2019):

   \[ P = \frac{W_{out}}{t}, \text{ kg/h} \]  
   \[ (3) \]

   **Where:**
   - \( t \) = time of test duration (hr.).

4) **Pelletizing efficiency:** The pelletizing efficiency (\( \eta_p \)), % is the ratio between the quantity of feed pelleted and the total feed input (Okolie et al. 2019). It was determined for 1 kg of feed meal using the following relationship:

   \[ \eta_p = \frac{W_{out}}{W_{in}} \times 100 \]  
   \[ (4) \]

   **Where:**
   - \( W_{out} \) = Weight of output pelletized feed, kg, and
   - \( W_{in} \) = Weight of total feed input, kg.

5) **Energy requirement:** Energy requirement in kW.h/Mg was calculated using following equation (El-taheer et al. 2013).

   \[ \text{Specific Energy} = \frac{P_R}{P} \]  
   \[ (6) \]

   **Where:**
   - \( P_R \) = Required power, kW.
   - \( P \) = Machine productivity, Mg/hr.

6) **Chemical analysis:** The chemical analysis is one of the most important tests that are conducted on the feed to evaluate and know the proportions of the components needed by the animal. One of the most important of these tests is to know the percentage of protein present in the pellets, ASH, moisture content and fats.

**RESULTS AND DISCUSSION**

**Factors affecting bulk density, Kg/m³**

Figure 9 shows the effect of moisture content, die diameters and mixing duration times on bulk density.

It was observed that the bulk density decreased by increasing moisture content, while it increased by increasing mixing time and die diameter. The maximum value of bulk density was 940±1.2 Kg/m³ at die diameter of 8 mm, mixing time of 20 min and moisture content of 70.09 %. The minimum value of bulk density was 180±0.7 Kg/m³ at die diameter of 4 mm, mixing time of 10 min and moisture content of 81.35%. Higher density could be as a result of the good mixing of the components, the pellets are more compressed, which leads to an increase in its mass and thus an increase in the apparent density. It was noticed that bulk density, Kg/m³, % increased with the moisture content, %; die diameters, mm; and mixing duration time according to the following descending order [81.35<79.71<70.09, %]; [4<6<8 mm]; and [10<15<20 mm], respectively.
Factors affecting shear force, N

It was observed that the shear force decreased by increasing moisture content, while it increased by increasing mixing time and die diameter. The maximum value of shear force was 1.29±0.02 N at die diameter of 8 mm, mixing time of 20 min and moisture content of 70.09 %. The minimum value of shear force was 0.31± 0.04 N at die diameter of 4 mm, mixing time of 10 min and moisture content of 81.35%.

It was noticed that shear force, N, % increased with the moisture content, %; die diameters, mm; and mixing duration time according to the following descending order [81.35<79.71< 70.09, %]; [4< 6<8 mm]; and [10< 15<20 mm], respectively.

Factors affecting rupture force, N

It was observed that the rupture force decreased by increasing moisture content for vertical and horizontal orientation, while it increased by increasing mixing time and die diameter. The maximum value of rupture forces for horizontal and vertical orientation were 8.72±0.05 and 6.32±0.03 N at die diameter of 8 mm, mixing time of 20 min and moisture content of 70.09 %. The minimum value of rupture forces for horizontal and vertical orientation were 1.01±0.04 and 0.94±0.07 N at die diameter of 4 mm, mixing time of 10 min and moisture content of 81.35%. It was noticed that rupture force, N, % increased with the moisture content, %; die diameters, mm; and mixing duration time according to the following descending order [81.35<79.71< 70.09, %]; [4< 6<8 mm]; and [10< 15<20 mm], respectively.
Factors affecting machine productivity, kg/hr

Figure 12 shows the effect of moisture content, die diameters and mixing duration times on machine productivity. It was observed that the machine productivity increased by increasing moisture content, mixing time and die diameter. The maximum value of machine productivity was 66±3.31 kg/hr at moisture content of 81.35%, die diameter of 8 mm and mixing time of 10 min. The minimum value of machine productivity was 20.1±2.05 kg/hr at moisture content of 70.09%, die diameter of 4 mm and mixing time of 20 min. It was noticed that machine productivity, kg/hr increased with the moisture content, %; die diameters, mm; and mixing duration time according to the following descending order [70.09<79.71<81.35, %]; [4<6<8 mm]; and [20<15<10 mm], respectively.

Factors affecting mixing efficiency:

Figure 13 shows the effect of moisture content and mixing duration times on mixing efficiency. It was observed that the mixing efficiency increased by increasing mixing duration times, while it decreased by increasing moisture content. The maximum value of mixing efficiency was 95.2±6.77% at mixing time of 20 min and moisture content of 70.09±3.21%. The minimum value of mixing efficiency was 63.1% at mixing time of 10 min and moisture content of 81.35%. It was noticed that mixing efficiency, % increased with the moisture content, % and mixing duration time according to the following descending order [81.35<79.71<70.09, %]; and [10<15<20 mm], respectively.

Factors affecting pelletizing efficiency:

Figure 14 shows the effect of moisture content, die diameters and mixing duration times on mixing efficiency. It was observed that the pelletizing efficiency increased by increasing moisture content and mixing duration times, while it decreased by increasing die diameters. The maximum value of pelletizing efficiency was 97.9±4.67% at moisture content of 81.35%, die diameter of 4 mm and mixing time of 20 min. The minimum value of pelletizing efficiency was 60.1±3.55% at moisture content of 70.09%, die diameter of 8 mm and mixing time of 10 min. It was noticed that pelletizing efficiency, % increased with the moisture content, %; die diameters, mm; and mixing duration time according to the following descending order [70.09<79.71<81.35, %]; [8<6<4 mm]; and [10<15<20 mm], respectively.

Factors affecting specific energy requirement:

Figure 15 shows the effect of moisture content, die diameters and mixing duration times on specific energy requirement. It was observed that the specific energy decreased by increasing moisture content and die diameters, while it increased by increasing mixing duration times. The maximum value of specific energy was 109.45±11.11
kW.hr/Mg at moisture content of 70.09 %, die diameter of 4 mm and mixing time of 20 min. The minimum value of specific energy was 33.33±4.23 kW.hr/Mg at moisture content of 81.35%, die diameter of 8 mm and mixing time of 10 min. It was noticed that specific energy requirement, kW.hr/Mg decreased with the moisture content, %; die diameters, mm; and mixing duration time according to the following descending order [70.09<79.71< 81.35, %]; [4<6<8 mm]; and [20< 15<10 mm], respectively.

The constructed alternative feeds making machine successfully proved its ability to chop, mix and pelletize raw materials to produce alternative fodder. To get higher values of bulk density, the developed machine needs to be operated at lower moisture content for sprouted barley with larger die holes’ diameters and with longer mixing time. Decreasing die diameter and mixing time decreased shear and rupture forces at high moisture content for sprouted barley. Short mixing time of 10 minutes and larger die holes’ diameters gives higher machine productivity and reduce the required specific energy at sprouted barley moisture content of 81.35 %. Produce durability indicates the ability of produced pellet to withstand physical disintegration with the ability to withstand compression and resist impacts during storage and transportation. Produced feed had 9.1 % ash content, 21.26 % protein and the fat percentage was 1.98 %.

**REFERENCES**


ASAE (2003). Moisture measurement. American Society of Agricultural and Biological Engineers, ASAE Standard 352.2 FEB.


**CONCLUSIONS**

Figure 15. Effect of mixing time (min) on specific energy requirement (KW.hr/Mg).

Chemical analysis of the produced pellets:

Table 2 shows the chemical analysis of produced pellets. It is indicated that ash content was 9.1 %, protein was 21.26 % and fat was 1.98 %

<table>
<thead>
<tr>
<th>Test analysis</th>
<th>Test result</th>
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<tbody>
<tr>
<td>Moisture content %</td>
<td>9.23</td>
</tr>
<tr>
<td>Ash content %</td>
<td>9.1</td>
</tr>
<tr>
<td>Protein on wet WT%</td>
<td>21.26</td>
</tr>
<tr>
<td>Fat content %</td>
<td>1.98</td>
</tr>
</tbody>
</table>

Table 2. Chemical properties of pellets.

The constructed alternative feeds making machine successfully proved its ability to chop, mix and pelletize raw materials to produce alternative fodder. To get higher values of bulk density, the developed machine needs to be operated at lower moisture content for sprouted barley with larger die holes’ diameters and with longer mixing time. Decreasing die diameter and mixing time decreased shear and rupture forces at high moisture content for sprouted barley. Short mixing
El-Sheikha, A. M. et al.


