BIOLOGICAL ENGINEERING

LINEAR PROGRAMING MODEL FOR PELLETIZED BAGASSE RATION

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ABSTRACT

The aim of the present study is to predict new large animal feed ration using bagasse by densification process with the aid of soy bean, bran, corn, molasses, bagasse and slate using linear programing model to get the optimal feed mixture from the view point of minimization of the total cost and maximization of nutritional value of the animal feed. Bagasse of moisture content 10 ± 1 % w.b was crushed to 3 – 7 mm and prepared at three different controlled moisture contents 30, 35 and 40 %, three different mixture temperature 35, 50 and 65 ºC using controlled temperature water bath, then compressed through 6, 8 and 10 mm die diameters at three different pressure levels of 7.5, 10 and 12.5 MPa. The cost of the new alternative ration is less than the traditional one by 26 %.

INTRODUCTION

Egypt cultivates about (325) thousand faddans of sugar cane every year, which produce 4.87 million tons of bagasse. Sugarcane bagasse is a secondary by-product of sugar cane extraction factories. It is used in the manufacture of pressed fibrous woods, paper pulp and as fuel. Bagasse represents 25-30 % of the sugar cane plant **Ministry of Agriculture, Egypt (2014).** Sugarcane bagasse is the fibrous residue of Sugarcane after the extraction of juice. Bagasse, as agro-based fibers, have the composition, properties and structure that make them suitable for uses such as composite, textiles, pulp and paper manufacture and animal feed, among others **Narendra** and **Yang, (2005).** In order to reduce industry's operational cost as well as to meet the requirement of raw material for animal feed production, industry wastes must be processed and handled in an efficient manner.

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Due to its high moisture content, irregular shape and size, and low bulk density, waste is very difficult to handle, transport, store, and utilize in its original form **Sokhansanj et al., (2005).** Densification of waste into durable compacts is an effective solution to handling problems and it can reduce material waste. Densification can increase the bulk density of waste from an initial bulk density of 40-200 kg/m3 to a final compact density of 600-1200 kg/m3 **Adapa et al., (2007)**. The density of pellet is calculated from the mass and volume (measuring the length and diameter) of compacts. In general, the density of pellets from agricultural straw significantly increases with an increase in applied pressure **Adapa et al., (2010); Kaliyan** and **Morey, (2009) and Mani et al., (2004).** The density of pellet is calculated from the mass and volume (measuring the length and diameter) of compacts. In general, the density of pellets from agricultural straw significantly increases with an increase in applied pressure **Kaliyan** and **Morey (2009).** Also indicated that the durability of corn Stover or switch grass briquettes was significantly affected by pressure, moisture content and preheating temperature, while particle size did not have any significant effect. **Serrano et al. (2011)** found that the highest mechanical durability reached for barley straw pellets was 95.5% at moisture content of 19-23% (w.b.), while no pellets were formed below the 19% moisture content. According to **Ministry of Agriculture, Egypt (2014)** total bagasse yearly produced in Egypt is accounted 400000 ton. Most this huge quantity are incinerated in open areas causing a fatal effect to human beings. Present study aimed to change previously mention huge amounts of bagasse to be an alternative feed ration to prevent environment of this incredible source of pollution and converting it to be a solution to animal feeds and meat crises.

MATERIALS AND METHODS

3.1 MATERIALS

Experimental study was carried out in the workshop of the Faculty of Agricultural Engineering, Al-Azhar University Assiut, branch during 2015.

3.1.1 Raw material

SOY BEAN, CORN, BAGASSE, MOLASSES AND BRAN.

3.1.2 Raw material preparation
3.1.2.1 Collecting of samples

Sugarcane bagasse residues were collected after juicing process of about 42.7 % moisture content w.b, of a bulk density about 170 kg/m³. Samples were first sun dried and then cut into small pieces 2 – 3 cm followed by cutting of 3.0 - 7.0 mm. Wheat bran, soy meal, salts and metals were collected from open market in Assiut – Egypt and stored in clean polythene bags. Cane molasses were also stored in plastic jars till they are used in the present work.

3.2 Linear programming approach to the ration formulation problem

Linear programming model Microsoft Office Excel (2010) was developed to select optimal diet composition based on minimization of the total cost and maximization of nutritional value of the new selected nontraditional large animal feed ration. Microsoft Office Excel Solver add-Ins (2010) was used to solve the linear programming model to get the optimal feed mixture from the view point of minimization of the total cost and maximization of nutritional value of the animal feed.

In the program model grind grains: corn, wheat bran and soy bean of previously known nutritional components were used. Sugarcane crushed bagasse of 10 $\pm$1% moisture content and molasses ratios of 15 % were also fed to the model for maximizing the nutritional value of the new and nontraditional alternating large animal feed ration and minimization of their total cost. Diets composition was optimized by the model.

To determine the feed pellet ingredient combinations the model of a linear programming was built as follows:

The objective function:

$$Z = c_1x_1 + c_2x_2 + c_3x_3 + c_4x_4 + c_5x_5$$

Where: Z = Minimum cost.

The model is subjected to the following constraints of the basic nutritional requirements for large animal feed (Ruminants) recommended by the National Research Council **NRC (1994)**:

A $a_1x_1 + a_2x_2 + a_3x_3 + a_4ax_4 + a_5x_5 \geq 14$ %

B $b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 \geq 65$ %

C $c_1x_1 + c_2x_2 + c_3x_3 + c_4x_4 + c_5x_5 \leq 15$ %

D $x_3 = 5 \ or \ 10 \ or \ 15$ %

E $x_4 \geq 20\%$

F $x_1 + x_2 + x_3 + x_4 + x_5 = 90 \ unit$

G $x_1, x_2, x_3, x_4 \ and \ x_5 \geq 0$

Where: X_1, X_2, X_3, X_4, and X_5 soy bean, corn, molasses, bagasse, and bran respectively, and;

A: Crude protein ratio (CP);

B: Total digestible nutrients (TDN) system as a measure of energy,

C: Crude fiber (CF),

D: Molasses ratio,

E: Sugarcane bagasse,

F: Quantity of components per mass unit and

G: No negativity constraint.

3.3 Pellets forming piston-cylinder assembly
The mechanical forming process involves the application of a compressive force on the material enclosed in a cylinder of an inside 8 cm diameter, 20 cm length, 9 die holes and replaceable dies diameters of 6, 8 and 10 mm used for compressing pellets Fig. (3.1) showed carver 12 ton hydraulic unit Source of manufacture: USA, Model: 3912 and Max load: 12 ton.

3.4 Measuring instruments
3.4.1 Digital Caliper
Digital vernier caliper was used for measuring pellets dimensions Model: TESA 1p65, Useful range: 0 -150 mm and Full accuracy: 0.01 mm

Fig. (3.1): Carver 12 ton hydraulic unit

3.4.2 Electric digital balance

Weights of samples were measured by an electrical balance source of manufacture: Korea, Model: THP-600, Useful range: 600 g and Accuracy of 0.01 g.

3.4.3 Electrical heater

Electrical heater used for heating pellet mixtures before compression processing.

3.4.4 Electric oven

Electric oven used for oven method moisture contents evaluation of the following specification drying oven Model: 655F and Useful range: 250 ºC.

3.4.5 Infrared thermometer

Infrared thermometer used for mesuring formating mixtures temperaturs of the following specification Model: 8865, Useful range: 50-580 ºC and having accuracy of 0.1 ºC.

3.5 Measurements

3.5.1 Moisture content

The moisture content was determined according to the method of **ASAE (2003)** S358.2**.** About 25 g of the mixture samples were placed in an oven

at 103 °C for 24 h. The moisture content was then calculated according to the following equation:

$$MC = \frac{W_m - W_d}{W_m} \times 100 \quad \text{……. (3.1)}$$

Where: M. C: Moisture content of basis %.

W_m: Moist weight g and W_d: Dry weight g.

Produced pellets were dried at room temperature until their moisture content reached about 10 % ± 1 %.

3.5.2 Pellet quality Evaluation
3.5.2.1 Pellet durability
Durability measurement of a single pellet for three replicates was carried out using drop test. Single pellet was dropped from a 1.85 m height on a metal plate. The mass retained is expressed as the percentage of the initial weight **Al-Widyan** and **Al-Jalil (2001).** Each drop test was replicated three times. The durability was calculated as:

$$\text{Durability \%} = \frac{\text{Mass of pellets after dropping}}{\text{Mass of pellets before dropping}} \times 100 \quad \text{… … (3.2)}$$

3.5.2.2 True density of Pellet
The density of each individual pellet was obtained by measuring the length, diameter and mass using electronic caliper and electronic balance. To have uniform length, the edges of the pellets were smoothed according to **Shankar et al. (2007)** and **Peter, (2014).** Pellet density is an average value of three replicates. The true density was calculated as

$$V_b = \frac{\pi}{4} D^2 L \quad \text{…………… … (3.3)}$$

$$\rho_d = \frac{m_b}{V_b} \quad \text{… … … … … …. … . … (3.4)}$$

Where: ρ_d : True density of pellets, (kg/m³)

m_b : Mass of the pellets (kg); and

V_b : Volume of the pellets (m³)

3.2.2.3 Bulk density
The bulk density of pellets is calculated by measuring the bulk weight of the pellets filling a pre-defined volume according to **ASABE (2002).**

Measurements were repeated three times for all samples. The bulk density was calculated as:

$$\rho_{b=} \frac{m_c}{v_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

Where: ρ_b: Bulk density (kg/m³)

m_c : Mass of sample in the cylinder (kg) and

v_c : Volume of cylinder (m³).

3.2.2.4 Cost analysis

The operating cost of producing the new untraditional alternation large animal feed (L. E./h) was calculated according to **Awady (1978)** and the production cost for producing one ton of the alternation animal feed was also calculated as follows:

$$\text{Production cost} = \frac{\text{Operation cost (L.E./h)}}{\text{Machine productivity (ton/h)}} \text{ L.E./ton}\ldots\ldots (3.6)$$

VI. RESULTS AND DISCUSSION

4.1 Prediction of ration formulation using linear programing

In present study linear programing Microsoft Excel (2010) was used for minimizing predicted alternative nontraditional large animal feed rations costs and maximizing their nutritional values using the **NRC (1994)** recommendations. The new nontraditional alternative ration was predicted and cleared in Table (4.1)

Table (4.1): Composition of the predicted ration

Composition	Percentage %
Bagasse	25
Soy- bean meal	21
Wheat bran	29
Molasses	15
Calcium carbonate	5
Vitamins	3.5
salt	1.5
Total	100 kg

According by NRC 1994.

4.2 Pellet quality evaluation

In present work predetermined different rations composition using simplex model was used for producing compressed pellet.

The effect of three different pressure levels 7.5, 10 and 12.5 MPa on true density, bulk density and durability were studied with changing other different operating parameters namely: three different controlled moisture contents 30, 35 and 40 %, three different mixtures temperatures 35, 50 and 65 ºC and die diameters of 6, 8 and 10 mm were studied for evaluating the optimal pellet quality.

4.2.1 Effect of mixture temperature on durability of pellets.
Table (4.2) and Figs.(4.1), (4.2), (4.3) showed that there is a direct proportion between durability and mixture temperature for studied ranges of 35-65 ºC at constant applied pressure. These results agreed with **Abedin, (2012)**.

4.2.2 Effect of applied pressure on pellets durability.
Table (4.2) and Figs.(4.1), (4.2), (4.3) showed also that there is a direct proportion between applied pressure and pellets durability for all studied ranges of moisture contents 30-40 % w.b and mixture temperature ranges of 35-65 ºC and molasses ratio of 15 %.

For all studied ranges and condition linear form of durability as affected by applied pressure and mixture temperature were satisfied.

Table (4.2) and Figs.(4.1), (4.2), (4.3) showed also that maximum value of durability is 97.9 % at 8 mm die diameter, 30 % moisture content, applied pressure 12.5 MPa and 50 ºC.

Figs.(4.1) through (4.3) cleared that durability increases from 1.33 to 9.61 when applied pressure increased by 1 MPa at constant moisture content w.b, mixture temperature range from 35-65 ºC from all tested die diameters in the pressure work.

Large slope does not used as an indication for optimal durability of pellets. Optimal durability may by occurred due to interactions between operational parameter, i.e die diameter, mixture temperature, moisture content and increment of temperature due to applied pressure that decompose the fibrous components of lignocellulose of bagasse, which agreed with **Samson and Duxbury (2000).**

Table (4.2): Values of durability as affected by applied pressure   and different mixing temperatures at constant moisture content w.b

| Die size mm	Moisture %(.w.b)	T. °C	Durability (%)		
			Pressure Mpa		
			7.5	10	12.5
6	30	35	75.1	85.1	88.1
		50	78.9	87.9	90.9
		65	83.4	91.1	97.4
	35	35	84.1	87.8	92.4
		50	88.9	89.9	93.9
		65	91.1	91.4	95.1
	40	35	72.1	81.8	87.1
		50	89.9	91.9	94.9
		65	91.7	93.9	94.4
8	30	35	88.1	92.6	95.1
		50	90.9	93.9	97.9
		65	91.0	94.4	97.4
	35	35	85.1	91.1	93.1
		50	91.4	92.9	94.8
		65	92.4	93.4	95.4
	40	35	84.1	89.1	91.1
		50	90.9	93.3	93.9
		65	93.4	95.4	95.4
10	30	35	79.13	91.13	93.13
		50	86.9	92.9	94.9
		65	91.4	93.8	96.2
	35	35	89.13	90.13	93.13
		50	89.5	91.35	92.9
		65	89.37	90.96	92.07
	40	35	69.13	78.63	88.35
		50	84.51	86.35	90.90
		65	84.36	87.37	91.37
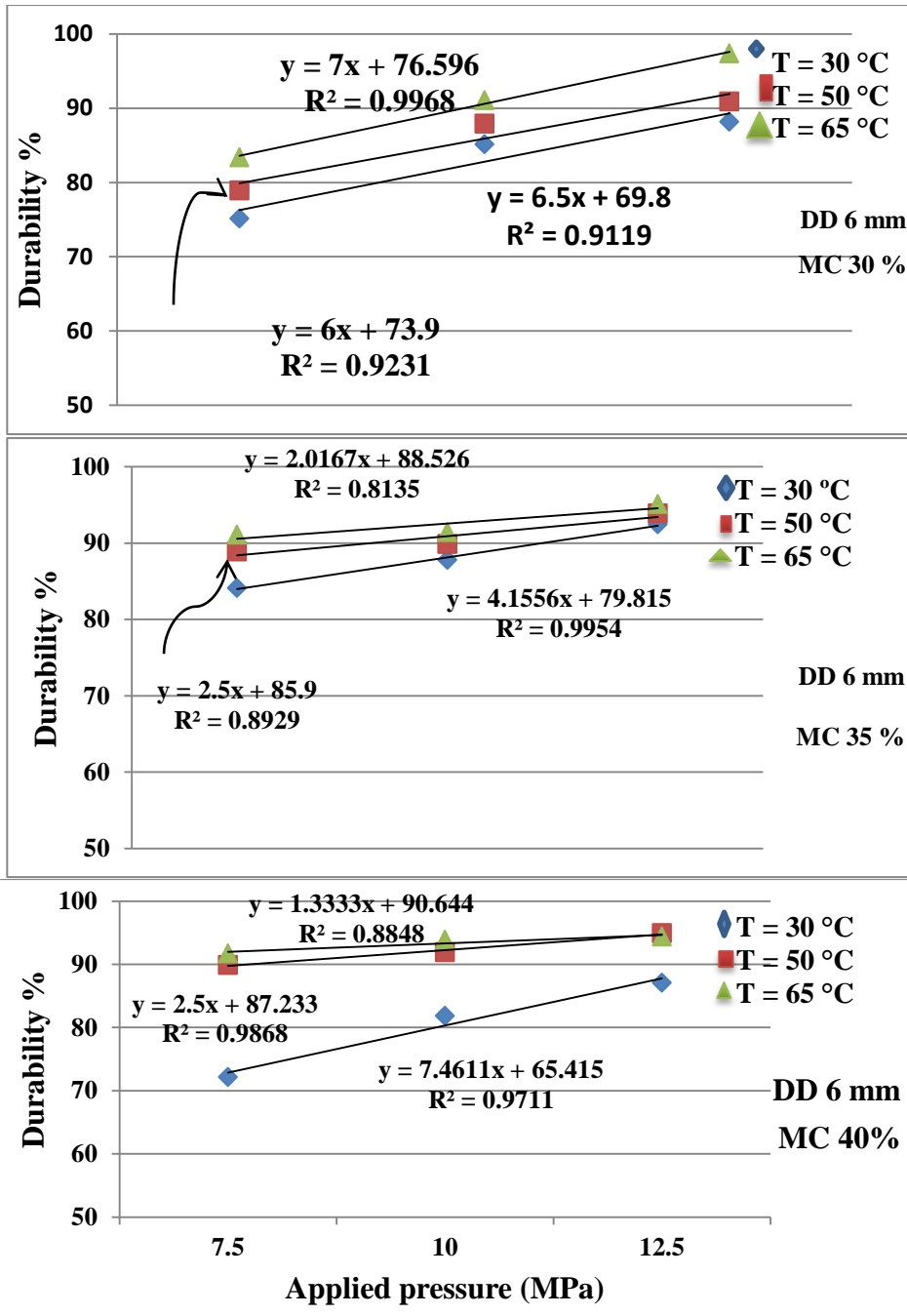
Fig.(4.1): Values of durability as affected by applied pressure and different mixing temperatures at constant moisture content w.b for die diameter 6 mm
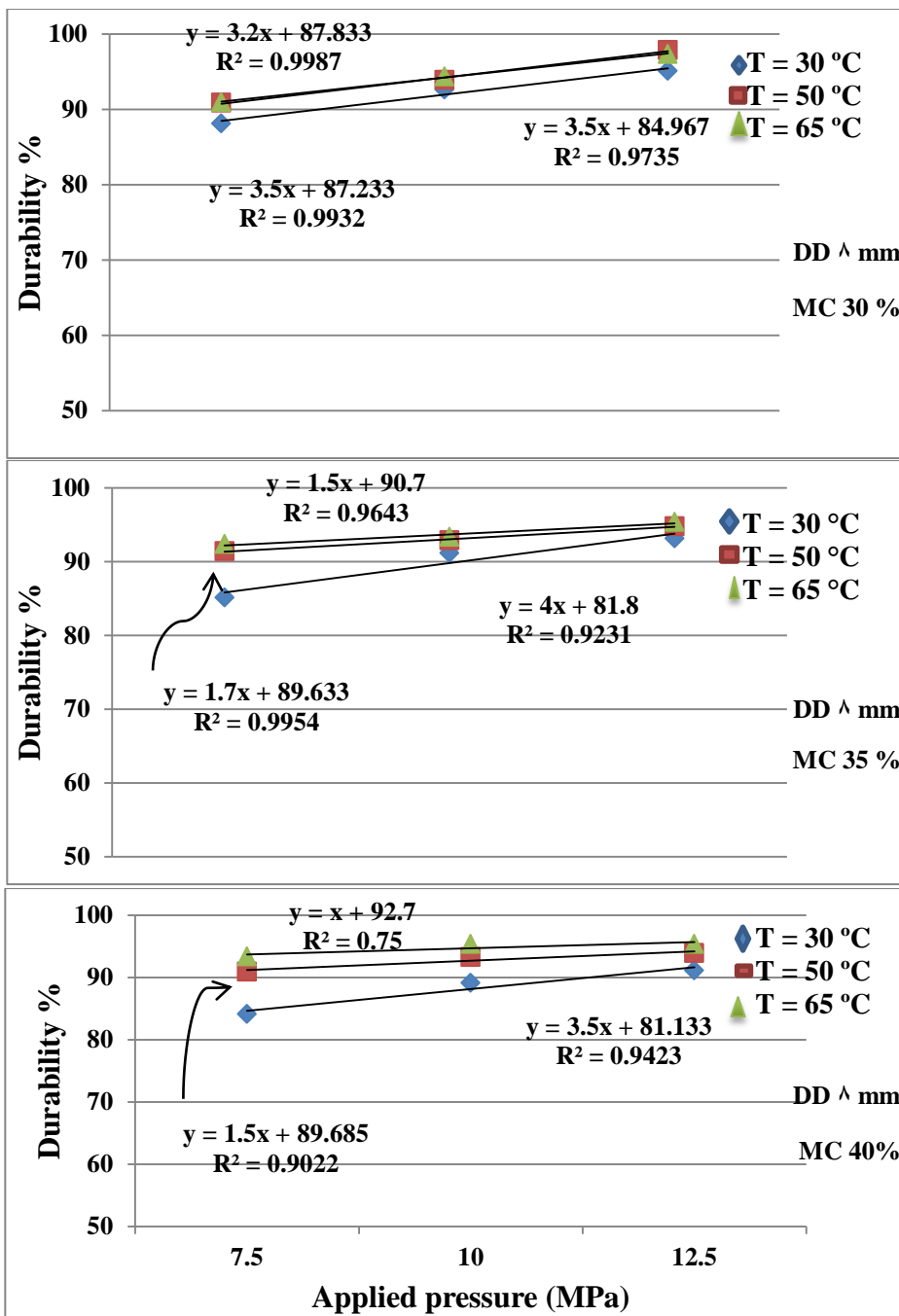
Fig.(4.2): Values of durability as affected by applied pressure and different mixing temperatures at constant moisture content w.b for die diameter 8 mm
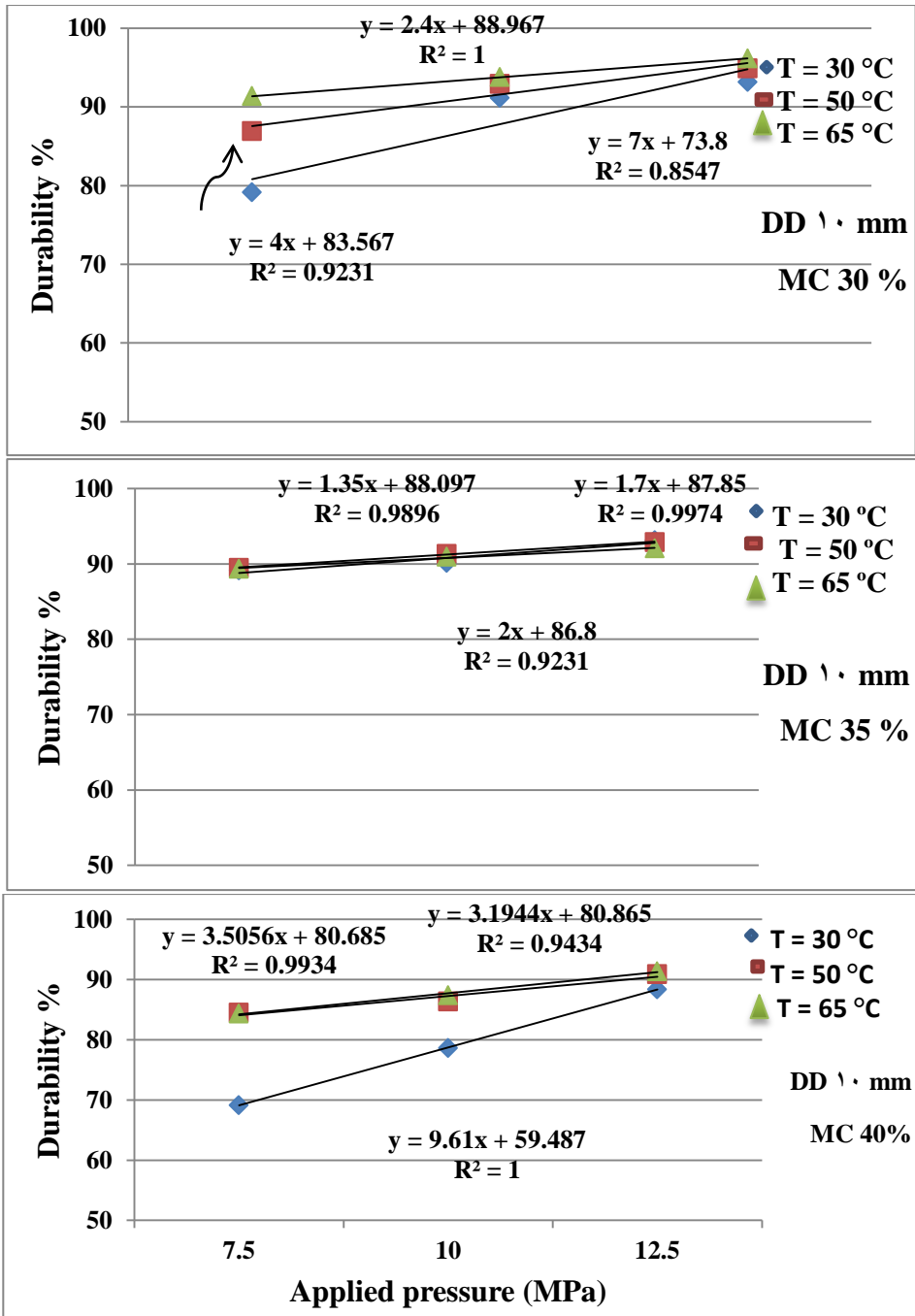
Fig.(4.3): Values of durability as affected by applied pressure and different mixing temperatures at constant moisture content w.b for die diameter 10 mm

4.2.3 Bulk and true densities of the optimal pellets construction

Bulk and true densities of the optimal pellets were evaluated as reported in methods, Table (4.3) showed minimum and maximum values of durability and both bulk and true density evaluated and their boundary and process condition.

It is clear that bulk and true density of optimal durability 97.9 % are 770.4 and 895.3 kg/m³ respectively.

Comparing optimal pellets bulk and true density with that of raw sugarcane bagasse, it is clear that bulk density of pellets is 4.5 times that of raw bagasse and true density of pellets is 5.3 times bulk density of bagasse. These results showed to what extent densification process helps in transportation, storage and handling processes, moisture content 10 % $\pm$ 1 w.b of pellets is reflected to extending shelf life of these faster decomposable resides.

Table (4.3): Maximum and minimum values of pellet durability % and their true and bulk densities kg/m³

Item	Durability %	True density kg/m³	Bulk density kg/m³	Process condition				Remarlees
				D.D mm	M.C %	P. MPa	T. ºC	
Max.	97.9	895.3	770.4	8	30	12.5	50	**Optimal**
Min.	69.1	724.9	530.9	10	40	7.5	35	

4.3 Cost analysis

Table (4.4) and Figs. (4.4), (4.5) showed that hourly costs of pelleting machine were 16.25 LE/hr.

Figs. (4.4), (4.5) depicted that the cost of producing one ton of the alternative feed produced for large animals for 8 mm die at 12.5 MPa and 30 % moisture content treatment recommended as an optimal pellet produced using linear programing was 2216.81 L.E./ton as compared to 3000 L.E./ton of traditional marketed feed for large animals with same nutritional value i.e. protein content and other feed components.

These results cleared that one ton of produced alternative feed in the present work cost 74 % of common traditional marketing feeds, and decreasing the costs of one ton cost by 26 % or 780 L.E per one ton Fig.(4.5). On the other hand, decreasing pollution caused by residues

incineration through open burning areas, and directly affects the environment due to reducing the emittance of the greenhouse gases and decreasing also atmospheric and ground temperatures, protecting human beings from a fatal effect.
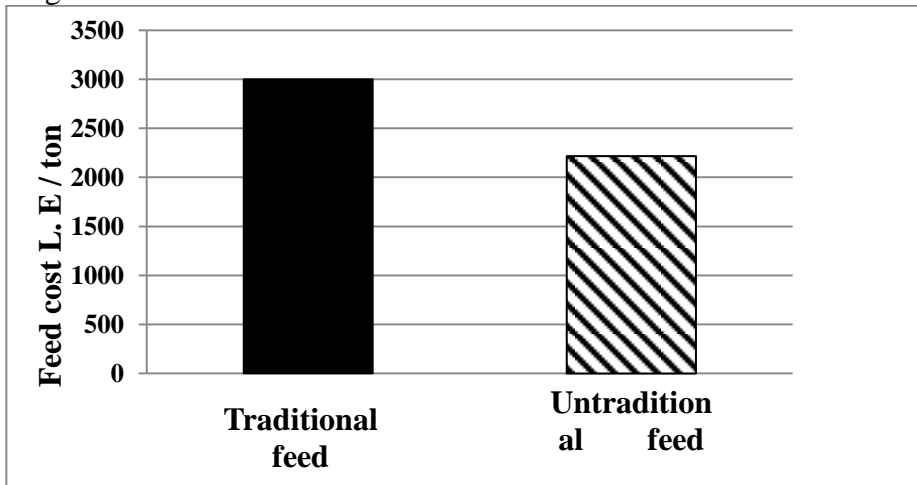

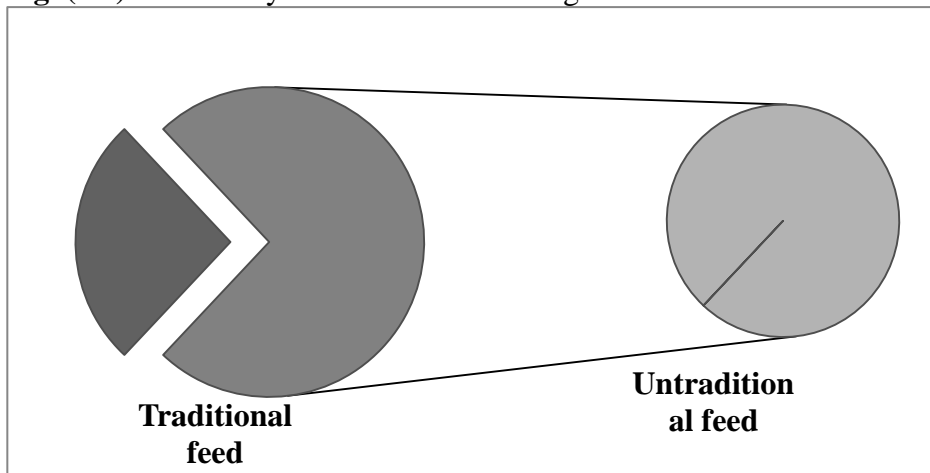**Fig. (4.4):** Cost analysis of untraditional large animals feed L.E/ton

Fig.(4.5): Comparison between traditional and untraditional large animals feed

SUMMARY AND CONCLUSION

This research was carried out for maximizing the utilization of sugarcane juicing residues with the aid of densification process, and converting it to be feed ingredient for large animals of pelletized form which play an

important role in preventing environment of fatal effect caused by direct incineration of these residues through open burning areas. So this research was extended to include five essential points:

1-   Linear programing using Microsoft Excel 2010 which is supported with defined molasses ratio 15%, 10 % salt, vitamins, minerals and the following other undefined quantities of soya ,corn, bagasse, bran. Proximate analysis of these undefined quantities based on NRC 1994 are used. The output of the program were

-       **For molasses ratio of 15 % the output of the model was**: Soya = 21%, corn= 0, bagasse = 25%, bran= 29%, salt, vitamins, and minerals = 10%.

Results concluded that:

•   There is direct proportion between all quality items and the applied pressures and mixture temperatures.

•   Linear form is satisfied for specifying relationships between quality items and the applied pressures.

•   Optimal pellet processed is selected based on durability of 97.9 %. The following are boundary conditions used for these pellets processing: 8 mm die diameter, 12.5 MPa applied pressure, 30 % moisture contents wet basis and processing temperature of 50 $^{\circ}$C.

•   Physical and mechanical characteristics of the optimal selected pellets i.e. true, bulk densities and durability were 895.3, 770.4 kg/m^3 and 97.9% respectively.

2-   Cost analysis of the selected optimal alternative large animal feed of the same nutrient components showed that one ton of the alternative feed costs 2216.81 L.E. compared to 3000 L.E. of the marketed traditional one i.e. it is cheaper by 26 % than that of the marketed traditional one. On the other hand using 400000 ton of bagasse in animal feeding serves in preventing environment of fatal effects of direct incineration of these residues in open areas.

<u>RCOMMENDATIONS</u>

1-   Optimal operating conditions to produce the pelletized alternative large animal feed   ration formulation are: die diameter of 8 mm, applied pressure of 12.5 MPa, mixture temperature and moisture content wet basis 50 $^{\circ}$C and 30 % respectively.

2-   Using the huge amount of the bagasse residues in producing this recommended animal feed, serves in preventing environment of fatal effects of direct incineration of these residues in open areas.

3-   Using the huge amount of the bagasse residues in producing this recommended animal feed, helps increases meat production and may be considered to be a solution of animal feeds and meat crises.

4-   Using the huge amount of the bagasse residues in producing this recommended animal feed may change the position of Egypt from animal feeds and meat importing country to be satisfied or exporting county which can be reflected on the foreign currency reserve.

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الملخص العربى
نموذج للبرمجة الخطية لعليقة مصاصة القصب المصبعة

طارق حسين غانم[1] ، محمد أحمد شتيوى[2] ،محمد ممدوح جعيصه[3] ، محمود بدرى جمعه[4]

يهدف البحث الى استخدام نموذج للبرمجة الخطية لتصنيع عليقة من مصاصة القصب المصبعة عن طريق بعض الإضافات والعناصر الغذائيه و كبسه ليتحول الى علف للحيوانات الكبيره، ليقى البيئه من التأثيرات المميته الناجمه عن حرق هذا المخلف والذى يقدر بـربعمائة الف طن سنوياً فى الأراضى المفتوحه. وقد امتدت هذه الدراسه لتشمل نقاط رئيسيه هى:

١- استخدام البرمجه الخطيه لبرنامج الإكسل ٢٠١٠ فى تركيب عليقة مماثلة للمتاح فى السوق المحلى لأعلاف الحيوانات الكبيره حيث كانت مدخلات البرنامج ١٥ % مولاس بالإضافه الى مطحون الصويا والأذره ومخلف القصب والنخاله و ١٠% من الأملاح والفيتامينات والمعادن. وقد إرتكز البرنامج على تحليل المكونات لتلك المواد طبقاً للمجلس القومى لبحوث الماشيه الكبيره (NRC) عام ١٩٩٤م .

٢- تم إختيار أفضل معامله على أساس أعلى متانه حيث أن هذه الخاصيه من أهم الخصائص التى لها عظيم الأثر فى عمليات النقل والتداول والتخزين، وكانت العينه المثلى التى تم على أساسها حسابات التكاليف تحت ظروف تشغيل : قطر فتحة تشكيل ٨ مم و ضغط الكبس ١٢٫٥ ميجابسكال ومحتوى رطوبى على أساس رطب ٣٠% وحرارة خليط ٥٠ م° كما كانت مواصفات العينه: المتانه ٩٧٫٩% والكثافه الحقيقيه والظاهريه ٨٩٥٫٣ و ٧٧٧٫٤كج/م³ على التوالى.

٣- أوضحت الدراسه أن العلف البديل الموازى للعلف المتاح بالأسواق وبنفس المحتوى الغذائى هو الأقل سعراً حيث كان سعر الطن ٢٢١٦.٨١ جنيهاً مصرياً مقابل ٣٠٠٠ جنيهاً مصرياً لنظيره فى السوق المحلى ، إنخفض سعر العلف البديل المنتج بحوالى ٢٦ % عن نظيره بالأسواق. هذا بالإضافه الى حماية البيئه من الأمراض المميته الناتجه عن حرق تلك المخلفات فى المساحات المفتوحه.

التوصيات

١- ظروف التشغيل المثلى لإنتاج المصبعات : قطر فتحة تشكيل ٨ مم و ضغط الكبس ١٢٫٥ ميجابسكال ومحتوى رطوبى على أساس رطب ٣٠% وحرارة خليط ٥٠ م° .

٢- إستخدام كميات مخلفات عصارات القصب بالكامل لإنتاج العلف البديل يقى البيئه من أخطار حرق تلك المخلفات المميته فى المساحات المفتوحه.

٣- إستخدام كميات مخلفات عصارات القصب بالكامل لإنتاج العلف البديل يزيد من إنتاج اللحوم للسوق المحلى وقد يعد حلاً لأزمة الأعلاف واللحوم مما يسهم فى توفير لإحتياطى رأس المال الأجنبى.

٤- توفير وفتح مجالات جديده لتشغيل الشباب والعماله.

١ -أستاذ الهندسة الزراعية – كلية الهندسة الزراعية – جامعة الأزهر – القاهرة .
٢ - أستاذ مساعد الهندسة الزراعية – كلية الهندسة الزراعية – جامعة الأزه – القاهرة .
٣ - مدرس الهندسة الزراعية – كلية الزراعية – جامعة الأزهر – فرع أسيوط – القاهرة .
٤ - معيد الهندسة الزراعية – كلية الزراعة – جامعة الأزهر – فرع أسيوط – القاهرة .