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Development and Performance Evaluation of a Power Operated Coconut Dehusker

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ABSTRACT

The present study was conducted at College of Agricultural Engineering and Technology, OUAT Bhubaneswar to develop and evaluate the performance of a power operated coconut dehusker suitable among the coconut growers of the state, Odisha. Dehusking of coconut is a very tedious job and many of the laborers show reluctance for this work as it causes injury to them by following traditional method. Development of a suitable coconut dehusker is therefore very much important in the state of Odisha where there is a great potential for coconut cultivation and marketing of commercial products from coconut husk. Hence the aim of the study was to develop a power operated dehusker which would become safe to operate, easy to fabricate, commercially feasible and economically viable. It was observed that the dehusker developed could dehusk 300 numbers of nuts per hour with a dehusking efficiency of about 92 percent.

Key words: *Coconut*, *Coconut dehusker, Copra, Coir, Dehusking efficiency*

INTRODUCTION

Dehusking is the process of removing the outer cover called husk from the coconut to get two important commercial products such as copra or dried kernel and fibre or coir. Copra yields oil and oil cake where as fibre produces carpets/mattresses and coir pith briquettes. Coconut shell obtained after dehusking is also a very useful industrial product to get coconut shell charcoal, activated carbon and coconut shell powder which have a good market value (Mishra and Sutar, 2010). Dehusking is therefore an important operation for coconut processing industry. The coconuts reaching markets are either partially husked or dehusked as per demand and requirement in distant markets. Coconuts meant for copra making are fully husked. Coconuts meant for distant market places are left with some fibres covering the eyes or on all around the nuts. Such partially husked coconut minimizes the breakage during transportation and attains longer keeping quality. It is also observed that even when coconuts are fully husked, a tuff of husk is left at the end of the nut over the eyes as it is considered to be auspicious and believed to preserve the nuts from spoilage. It has been reported that about 20 per cent of the total coconut produced in Odisha are consumed as tender nuts and 5 per cent are retained by the farmers for household and seed nut purposes (Anonymous, 2012). About 42 per cent of the coconut produced is consumed in the state itself and 33 per cent are exported to the other states like Bihar and Madhya Pradesh where cultivation of coconut is not favouable (Kumar and Kapoor, 2010). Hence dehusking of coconut needs to be done not only to increase the bulk density for easy transportation but also to process quickly for industrial purposes. Mechanization of dehusking operation is needed in the state like Odisha as coconut is one of the most important plantation crops of the state. The area under coconut production in the State is about 43.3 thousand hectares producing 296.05 million nuts. The present productivity of the crop has been reported to be 8741 nuts per hectare as against the productivity of 6285 nuts per hectare in India (Anonymous, 2012a).

The most frequently used dehusking method in the state is by the use of pointed metal spike, secured in the ground in a slightly slanting position, with the pointed ends upwards. The nuts are brought down with force on the spike, followed by twisting the nut sideward against the spike, causing loosening of the husk. Care is taken for the desired entry of the sharp end of the spike into the husk so as to avoid the damaging of shell. It is therefore clear that dehusking is a hard work, and may cause frequent injury to the operator. This job is not very popular as it is often difficult to find labour for this operation due to the every possibility of accidents. It involves a lot of drudgery and needs precaution against injury. Since dehusked coconut is an important material of commerce, dehusking needs to be mechanized. This study was therefore taken up with the objectives to develop a power operated coconut dehusker, to study its performance in terms of number of nuts dehusked per hour along with dehusking efficiency for different varieties of coconut available in Odisha, and to work out the economics of using power operated coconut dehusker.

MATERIALS AND METHODS

A coconut dehusker was developed which was operated by an electric motor with a reduction unit for actuation of sharp edged metallic fingers (one fixed and other movable) with the help of a movable cam to dehusk the manually fed coconut (Fig. 1). The various components of the dehusker were: a prime mover - I hp motor, reduction unit (for reducing speed of motor), belt and pulley, shaft, cam, lever and knife, hand protecting cover (safety ring), and concave chute. The prime mover used for the study was an electric motor of 1 hp capacity running with 1440 rpm and fitted at the bottom of the experimental set up. The reduction unit was used to reduce the rpm of motor to 25 rpm so that coconut could be easily fed to the fingers by their slow movement. Power was available at the pulley connected to the prime mover. With the help of belt and pulley arrangement, the power was transmitted to the shaft of the coconut dehusker. An idler pulley was used to maintain the belt tension. The pulley at the end of the shaft of dehusker revolved with 15 rpm and the power was finally transmitted to the cam. The cam was attached to the other end of the shaft of the coconut dehusker. This cam transmitted the rotary motion to the linear motion of the movable finger through a lever. The two fingers were hinged in such a way that one finger was fixed and other one moved forward and backward periodically to make a separation of approximately 5 cm between them. After switching on the motor, the operator was to feed the coconut on the sharp edge of the knives when both the knives were closer to each other. When the knives were separated from each other, the husk in the coconut was loosened and then the coconut was again put on the knives when both the knives were closer to each other for second time for further loosening of the husk at the other portion of the nut (Fig. 2). This practice was repeated 3-4 times for complete loosening of the husk. Then the loosened coconut was handed over to the helper who was to completely remove the loosened husk from the nut and the nut was now in dehusked condition for its easy transportation and for use in some other purposes. The technical details of the dehusker are given in Table 1.

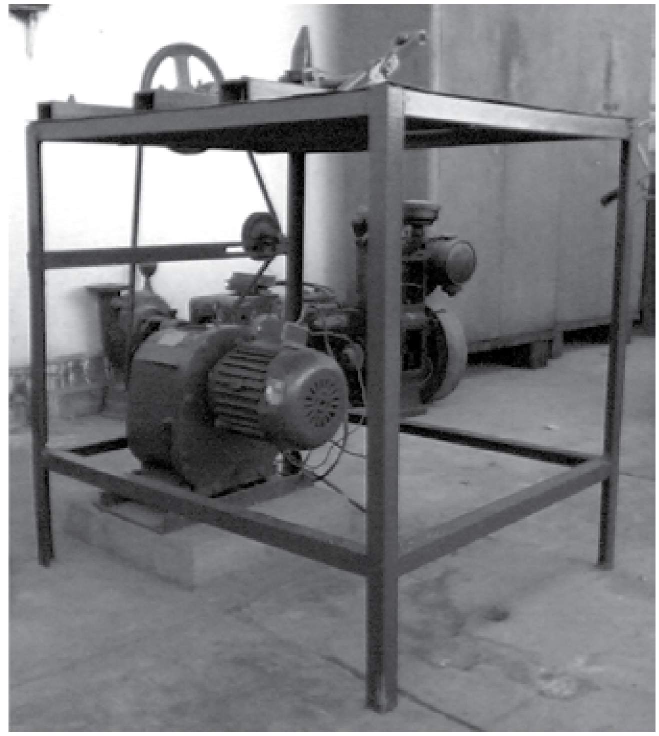

Fig. 1: Power operated coconut dehusker

Fig. 2: Working of power operated coconut dehusker

The freshly harvested coconuts were generally dried in the sun for 8-12 days to reduce the moisture content suitable for easy dehusking. Before dehusking, a small strip of the husk was removed from any one coconut out of a heap of coconuts harvested at the same time. The removed husk was put inside the oven at I05 ^{0}C for 24 h for determination of moisture content. Before putting the husk inside the oven, the weight of the husk was taken. Then after 24 h, the dried husk was taken out of the oven and weighed again. After that the moisture content of the coconut was calculated. Usually the moisture content (M.C.) of a substance is expressed in percentage by weight on wet basis. At first the husk was weighed after dehusking. Then the remaining husk present in the coconut was removed completely from the dehusked coconut manually to know the total weight of the husk. For experimental purpose, three varieties of coconut like Sakhigopal, Guamal and Hazari were taken at different moisture contents. The dehusking operation was performed continuously for 20 minutes with a rest interval of 10 minutes for providing comfort to the operator. Finally the number of coconuts dehusked per hour was calculated for the same variety and at same moisture content for analysis. Dehusking efficiency was calculated using following equation:

Table 1: Technical details of developed coconut dehusker

S. No.	Item	Dimensions
1.	Table	770 mm × 960 mm × 960 mm
2.	Angle	40 mm × 40 mm × 5 mm
3.	mild steel sheet	2mm hick,770 mm × 960 mm
4.	Electric motor	1hp (740 Watt), single phase
5.	Pulley at the shaft (driven):-	250 mm
6.	Pulley at motor (driving):-	150 mm
7.	Idler pulley	125 mm
8.	V-belt	B 80
9.	MS shaft	640 mm length, 25 mm ∅
10.	Bearing and bearing housing	2 Nos.
11.	Knife	70 mm
12.	Nut bolts	9.37 mm
13.	Cam lift	137.5mm
14.	Knife opening	50 mm

Dehusking efficiency (%) =

$$\frac{\text{Weight of husk obtained after dehusking}}{\text{Weight of total husk present in the coconut}} \times 100$$

The experiment was conducted with two numbers of operators using different varieties of coconut at various moisture contents. Different moisture contents were obtained by sun drying of harvested coconuts from first day to tenth day. One was to feed the coconut into the dehusker and another one to assist him as and when required and to remove the rest of the husk from dehusked coconut according to the requirements. Interim rest was given to the operators looking into their comfortability. The economics of using power operated coconut dehusker was also worked out to know the feasibility of using the machine by the coconut growers. The performance of the dehusker has been mentioned in Tables 1 and 2.

RESULTS AND DISCUSSION

The coconut dehusker developed was evaluated with the different varieties of coconut most prevalent in Odisha with moisture contents varied from 5 to 45 percent. The results on the dehusked capacity of the machine are presented in Table 2. It was observed that the dehusked capacity for all the varieties was maximum in the moisture contents ranging from 10-15 percent. At the moisture content of about 15 percent, the husk was more loosened from the copra and required less impact force for dehusking. The number of coconut dehusked per hour was highest i.e. 330 in case of Sakhigopal variety followed by 324 for the other two varieties i.e. Guamal and Hazari. With more moisture content i.e. above 15 percent, the husk remained more attached to the copra resulting into more impact force for dehusking. However, when the moisture content became less than 15 percent, the husk was more dry causing difficulty in dehusking the coconut. Hence from the experimental observation, it was inferred that the moisture contents in the range of 10 to 15 percent were suitable for the machine to get better output. The cost of power operated dehusker is Rs 10,000/- and the operating cost per coconut to be dehusked was Rs. 0.10 only.

Similarly, the results of the dehusking capacity of the machine at the optimum moisture content i.e. at about 15 percent are presented in Table 3. It was found that there was no significant difference in the dehusking efficiency of the machine for all the three varieties i.e. Sakhigopal, Guamal and Hazari. However, the dehusking efficiency was observed to be highest in case of Sakhigopal variety (92.45%). It may be due to the low percentage of husk present in Sakhigopal variety compared to the other two varieties. The percentage of husk in Sakhigopal, Guamal and Hazari as observed was 44, 52 and 57 respectively (Mishra and Sutar, 2010).

Table 2: Testing of power operated coconut dehusker with different coconut varieties prevailing in Odisha

Varieties of coconut	Moisture content (% Wb)							
	0-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45
	No of nuts dehusked/h							
Sakhigopal	288	330	282	276	204	192	180	156
Guamal	282	324	276	270	210	192	174	150
Hazari	282	324	270	264	192	188	168	144

Table 3: Dehusking efficiency obtained by using power operated coconut dehusker with different coconut varieties at 15% moisture content.

Varieties of coconut	Total wt. of husk present in a coconut (gm)	Total wt. of husk removed during dehusking (gm)	Dehusking efficiency (%)
Sakhigopal	530	490	92.45
Guamal	533	492	92.30
Hazari	482	444	92.11

CONCLUSIONS

The number of coconut dehusked per hour by the machine was found to be highest i.e. 330 coconuts/h at 15 % moisture content. The dehusking efficiency was observed to be satisfactory i.e. 92%. The cost of use of the machine was also nominal i.e. Rs. 0.10 per nut for which it can be easily commercialized.

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Pasting Characteristics of Cassava at Different Extrusion Conditions

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ABSTRACT

The ability of a starch-containing food to form a paste or a gel is one of the principal factors that determine the texture and the quality of that food product. In this study, the pasting characteristics (cold and hot paste viscosity) of the extrudates of the flour and starch of cassava which are grown in Nigeria in large quantity processed from a locally developed extruder (Length to diameter ratio, L/D 12:1; compression ratio, CR 4.4:1) were determined. This was to serve as a means of finding alternative processing options for the crop. Stepwise regression and other follow up tests were employed to a factorial experiment in completely randomized design. Generally, both Hot Paste Viscosity (HPV) and Cold Paste Viscosity (CPV) vary inversely with duration of operation and decreased with increase in moisture content. The most stable of the products is Cassava Starch at 40% moisture content. Also, retro-gradation decreased with increasing extrusion time and moisture content (m. c.). The equations relating the various dependent and independent variables were established to predict the performance of the machine and the pasting properties of the products.

Key words: *Extrusion, Cassava, Hot and Cold Paste Viscosity, Stability of Food, Retro-gradation*

INTRODUCTION

In Nigeria and West Africa, starches from cereals, roots and tubers provide the highest source of dietary energy (Oke *et al*., 2013, Ihekoronye and Ngoddy, 1985). Nigeria's production of cassava (Manihot esculenta, Crantz), a starch-rich root tuber crops is the largest in the world, producing more than 70 million tones of cassava annually (Yisa, 2008). However, a high percentage of the crops are lost because of inadequate processing. There is need for alternative processing options for cassava to add to its value and for its sustainability. One of the means to arrest post-harvest losses is by expansion of the processing technology.

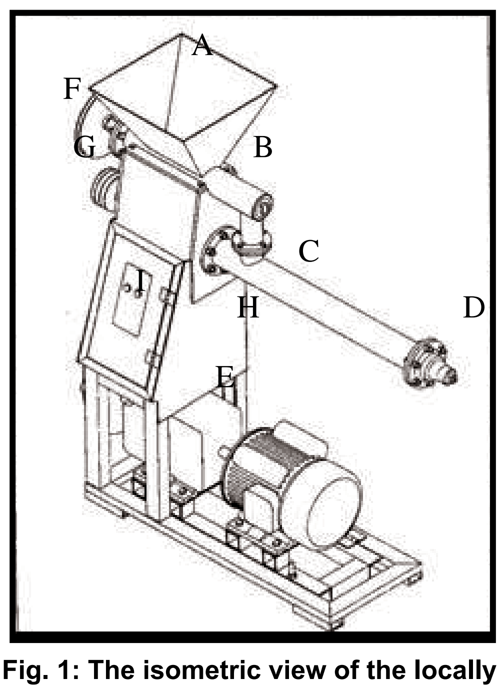
Food extrusion is a versatile process that helps in the expansion of the processing technology of crops. It is a process in which food ingredients are forced to flow under one or several conditions of mixing, heating and shear, through a die that forms and/or puff-dries the ingredients. Cassava as a starchy crop has high potential for production of extruded foods. Meanwhile it is obvious that cassava is not popular for production of extruded foods. Also, functional and pasting properties of flour and starch products are important for their use in the food industry. Characteristics of products formulated with starch, such as food thickeners and other flour or starch based products, are greatly influenced by functional and pasting properties (Niba et al., 2001). According to Osundahunsi (2005), pasting characteristics is necessary to determine the nature of food if it has to be in paste form. The ability of a starch-containing food to form a paste or a gel is one of the principal factors that determine the texture and the quality of that food product. Functional properties of starch such as pasting viscosity influence the textural and gross structure of the food products and they provide information that could be used to determine specific end user applications (Henshaw and Adebowale, 2004).

The viscosity of the paste to a large extent depends on the degree of gelatinization of the starch granules and the extent of their molecular breakdown. Un-gelatinized starch absorbs few water molecules at room temperature. The gelatinized starch however, absorbs water rapidly to form a paste at room temperature with further heating. Cold viscosity is an important property if the extruded starch will be used as an ingredient in the foods that require cold thickening capacity, like instant soups, creams or sauces. The aim of this study was to characterize the hot and cold paste viscosities of cassava flour and starch from a locally developed extruder.

MATERIALS AND METHODS

Cassava tubers (Manihot esculenta Crantz) TMS 30572, were sourced from experimental plots at the Federal College of Agriculture, Akure and processed into flour and starch respectively within 48 h of harvesting. The materials were passed through a 300 um sieve separately. The proximate analysis and moisture contents of samples were determined as described by AOAC (1995) Approved method.

The moisture content of each sample was an average of triplicate analysis. The extruder used in this study was the dry type and fabricated using locally available materials. The extruder was operated by one 4 kW electric motor through a gear reducer and belt and pulley transmission system. As a test rig, allowance was given for varying the screw configuration, feed rate, screw speed, die configuration (Fig. 1). The screw was of single flight, increasing diameter and tapering/decreasing pitch with a compression ratio of 4.5:1 and a length to diameter ratio of 12:1. Samples were fed into the extruder at a constant feed rate of 10 kg/h and 100 rpm screw speed. The experiment was a factorial experiment in completely randomized design comprising two levels of raw materials, three of moisture content and fifteen of duration of operation The extruded samples were dried according to Iwe *et al*. (1998), coarsely ground in a high speed laboratory blender (Waring Commercial Heavy Duty Blender, New Hartford, Conn. U.S.A.), milled in a domestic blender (Martex, Dawan) and passed through a 300 um sieve. Pasting properties (HPV and CPV) were determined as described by Amani (2004) with some adaptation. The instrument used to measure the pasting viscosity of the extrudates was the Rion Viscotester (VT – O4E – Japan) (Mouquet, 1998; Owolarafe *et al*., 2008). The samples were heated to 90^{o}C and the HPV determined. This was because all the materials under study had a gelatinization temperature much less than 90^{o}C. The test fluid was then cooled at a constant rate



LEGEND

A- Hopper
B- Feeding Conveyor
C- Extruder worm
D- Die Unit
E- Power train
F- Conveyor pulley
G- Extruder pulley
H- Extruder Housing
I- Control switch

Fig. 1: The isometric view of the locally developed extruder used for the study.

to 30°C. This value represents the CPV at that temperature the product is normally eaten or the room temperature.

Stepwise multiple regression analysis were carried out using Statistical Package for Social Scientists (SPSS 13.0). Microsoft excel © 2007 was used for plotting graphs. Regression analyses were employed to fit the experimental data to second-order polynomials.

RESULTS AND DISCUSSION

Proximate composition of the raw materials: The moisture content of the cassava starch and flour samples used were 1.82 and 1.46, respectively. Their dry matter proximate compositions were 87.22% carbohydrate, 7.36% protein, 1.86% fat, 0.30% fibre, and 1.44% ash for cassava flour and 96.65% carbohydrate, 0.31% protein, 1.27% fat, 0.11% fibre, and 0.20% ash for starch respectively. This result shows that the protein content of TMS 30572 variety of cassava was high when compared with other varieties used in previous studies. Even the amount of water needed to solvate it was higher than previous studies (Badrie and Mellowes, 1991; Mali and Grossman, 2001). This shows that efforts to improve cassava was focused on increasing yield, dry matter content, nutritional and protein content as a means to contribute to a sustainable and cost effective solution to malnutrition (Dixon *et al*., 2007). Other composition compared favourably with previous results.

Effect of extrusion variables on paste viscosity of cassava starch: Figures 2 and 3 show the effect of extrusion on Hot Paste Viscosity (HPV) and Cold Paste Viscosity (CPV) of cassava starch respectively at different moisture content, 100 rpm screw speed and 30 minutes duration of operation. Both Hot and Cold Paste Viscosity (CPV) varies inversely with duration of operation and decreased with increase in moisture content (30%- 40% but increased at 25% m. c). The reason for the increase at 25% m. c. was because for this case of extruder, cassava starch at moisture ≤ 25% w.b. blocked the rotation of the screw as there was no transition from the original floury nature to a melted state typical of most extrusion processing. This may be because the moisture content was not sufficient to solvate the starch polymers and allow them to

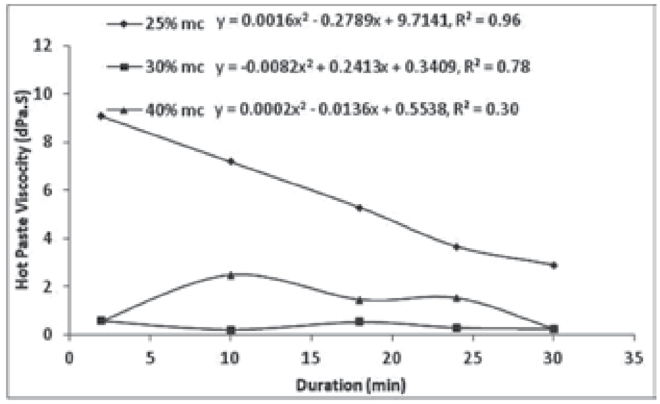


Fig. 2: Hot paste viscosity response of cassava starch to variable extrusion conditions at 100 rpm screw speed.

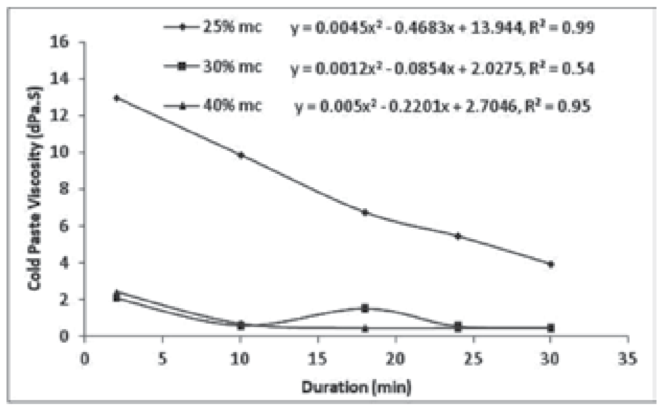


Fig. 3: Cold paste viscosity response of cassava starch to variable extrusion conditions at 100 rpm screw speed.

move freely in the mass. However, this was not the case for cassava flour. The CPV increased with the increase in moisture content of the feed in agreement with past reports. The values of HPV and CPV for the raw cassava starch were 9.7 and 16.47 dPas respectively. The lowest HPV and CPV of 0.25 dPas and 0.455 dPas were attained at 30% m. c. and 30 minutes duration of operation. HPV values at high extrusion times reflected molecular degradation. Similar findings were reported by Leonel et al. (2011), and Bhattacharya et al. (1999). The result of the stepwise regression analysis of the data is presented in Tables 1 and 2. R^2 of 50.5% for HPV was an indication that the relationship is not best described by a linear model. From Table 1, the moisture content has the highest contribution (51.8%) to R^2 of HPV of cassava starch extrudate. T test value in the table shows the extent (%) of

Table 1: Cassava starch hot paste viscosity

Models	Coefficients		T-test	Prob.	Adjusted R^2	F value	Prob.	VIF
1	B_0	20.764	4.023	0.002	0.505	6.111	0.009	
	Mc	-0.518	-3.105	0.009				3.354
	D_t	-0.598	-2.168	0.000				25.586
	dm	0.016	1.763	0.000				29.447

(Dt- Duration of extrusion, Mc-Moisture content, dm-interaction of Dt and M)

Table 2: Cassava starch cold paste viscosity

Models	Coefficients		T-test	Prob	Adjusted R^2	F value	Prob.	VIF
1	B_0	-3.943	-2.037	0.004	0.667	236.330	0.000	1.000
	Dt	0.955	15.373	0.000				
2	B_0	0.521	0.375	0.708	0.840	314.430	0.000	1.003
	Mc	0.981	22.889	0.000				1.003
	Dm	-0.012	-11.463	0.000				
3	B_0	-6.612	-2.449	0.016	0.851	227.540	0.000	
	Mc	1.212	14.020	0.000				4.370
	Dm	-0.030	-4.961	0.000				36.850
	Dt	0.553	3.046	0.003				39.031

(Dt- Duration of extrusion, Mc-Moisture content, dm-interaction of Dt and M)

the influence of the independent variable on the performance of the response variable. If positive, it indicates that an increase in the independent variable is contributing a positive percentage to the response variable. If negative, then a unit increase of the independent variable is decreasing the response variable. The F value indicates the significance of the total model. The variance inflation factors (VIF) were used to detect the presence of multi-co linearity. VIF measures how much the variances of the estimated regression coefficient are inflated as compared with when the independent variables are not linearly related (Neter et al., 1990). The VIF value for all parameter estimates for cassava starch HPV were 1.0 while those of its HPV greater than 1.0 Therefore, it can be concluded that multi-co linearity is not a problem in the case of cassava starch CPV. The more strongly correlated the independent variables are, the greater the need for controlling the confounding effects. However, the greater the inter-correlation of the independent variables, the less the reliability of the relative importance indicated by the partial regression coefficients. According to Neter et al. (1990) maximum VIF value in excess of 10 is often taken as an indication that multi-co linearity may be duly influencing the least squares estimates.

Effect of Extrusion Variables on Paste Viscosity of Cassava Flour: Figures 4 and 5 show the effect of extrusion on Hot Paste Viscosity (HPV) and Cold Paste Viscosity (CPV) of cassava flour at different

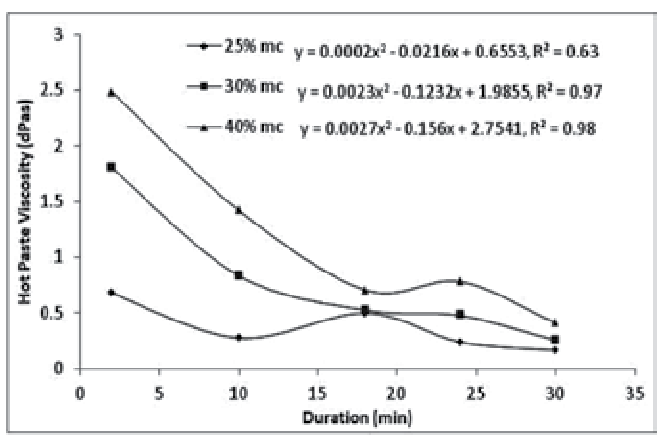


Fig. 4: Hot paste viscosity response of cassava flour to variable extrusion conditions at 100 rpm screw speed.

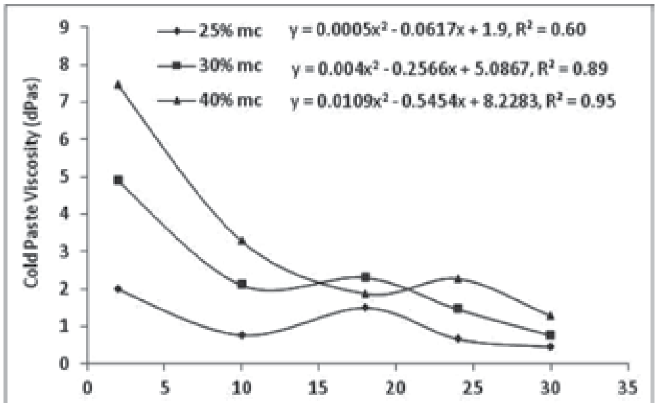


Fig. 5: Cold paste viscosity response of cassava flour to variable extrusion conditions at 100 rpm screw speed

moisture content, 100 rpm screw speed and 30 minutes duration of operation. Both Hot and Cold Paste Viscosities (CPV) vary inversely with duration of operation. However, both HPV and CPV for cassava flour increased with increase in moisture content (25% to 40%). The result of the statistical analysis is presented in Tables 3 and 4.

Stability of the products: Differences in HPV and CPV of the extrudates is an index of their stability. If the difference is low, it means the sample is very stable. The stability at 25%, 30%, 40% m. c. and raw unextruded samples were 1.02, 0.21, 0.19, 7.5 for cassava starch and 0.29, 0.49, 0.87, 10.09 for cassava flour respectively. Hence, it can be deduced that cassava starch at 25% m. c. is least stable, having the highest difference between its CPV and HPV values. This may be because at that temperature, there was no transition of the starch from the original floury nature to a melted state typical of most extrusion processing. This is followed by cassava flour at 40% mc. At moisture content 40%, CF was not well extruded. Also, the most stable of the products was cassava starch at 40% m. c. A low stability was a high indication of retrogadation tendency. There is generally an improvement in the stability of the extruded products when compared to the raw samples. The stability of cassava products were improved better than cereal products in previous studies (Fayose et al., 2009). According to Chang et al. (1998), starch with low moisture content extruded at a high temperature results in an extrudate characterized by a low degree of retrogradation, while starch with a moderate to high moisture content (190-260 g kg-1) extruded at a moderate temperature (125-190°C) produces an extrudate with a high degree of retrogradation. In this work, retrogradation decreased with increasing extrusion time and moisture content.

Table 3: Cassava flour hot paste viscosity

Models	Coefficients		T-test	Prob.	Adjusted R^2	F value	Prob	VIF
1	B_0	0.158	6.930	0.000	0.670	31.431	0.000	1.000
	D_t	0.139	3.332	0.000				
2	B_0	0.158	17.374	0.000	0.954	74.988	0.000	8.868 8.868
	D_t	0.018	12.876	0.000				
	dm	0.000	-8.660	0.000				

(Dt- Duration of extrusion, M-Moisture content, dm-interaction of Dt and M)

Table 4: Cassava flour cold paste viscosity

Models	Coefficients		T-test	Prob	Adjusted R^2	F value	Prob	VIF
1	B_0	3.054	3.869	0.002	0.442	11.103	0.005	1.000
	D_t	0.139	3.332	0.05				
2	B_0	.054	8.664	0.000	0.947	57.436	0.000	8.868 8.868
	D_t	0.535	9.629	0.000				
	dm	-0.012	-7.563	0.000				

(Dt-Duration of extrusion, M-Moisture content, dm-interaction of Dt and M)

CONCLUSIONS

The pasting characteristics of cassava extrudates from a locally developed single screw extruder at different conditions have been well studied. The study showed that 30572 variety of cassava have dry matter content and protein content than varieties in previous studies. Generally, both Hot and Cold Paste Viscosity (HPV and CPV) vary inversely with duration of operation and decreased with increase in moisture content. The most stable of the products is Cassava Starch at 40% moisture content. Also, retrogradation decreased with increasing extrusion time and moisture content. The equations relating the various dependent and independent variables were established to predict the performance of the machine and the quality of the products.

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Decision Support System (DSS) for Finished Feed Inventory Management

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ABSTRACT

The computer software for managing an inventory of perishable product such as processed livestock feed or finished feed is developed as decision support system (DSS). This DSS may be utilized as a stochastic model tool for production policy or as an entire production management portfolio for waste minimization. It is based on efficient and effective stock / store management under a set of random outcomes in discrete probability distribution pattern of finished feed demand, the experience of the policy/ portfolio/ firm is to be projected, and the outcome as optimum storage quantity is to be determined. Further, this process has to be repeated several times by using computer software (DSS) developed in C++. Stochastic modeling manages volatility and variability (randomness) into the simulation. The feed production manager may also vary about taking decisions on feed inventory based on intuitions and stage wise (most favourable to least favourable business prospects) random assessment. This DSS will be effective for excessive stock investment, inadequacy of stock to meet demand, and inaccuracy of stock records. The model validation may be sought in understanding a large, complex and untried problem situation for systematic and fresh stock delivery, at last enhancing the business prospects.

Key words: *Decision support system, Finished feed, Perishable commodity, Inventory (stock).*

INTRODUCTION

Inventory management is about two things: not running out, and not having too much. Essentially, inventory is a reserve system to prevent a stock out. Inventory is held in order to fill unexpected changes in demand and deliveries from suppliers. As demand fluctuates manufacturing firms are not sure how much to produce and put it in store on time as unwanted stock may be devalued due to perishable nature of product. However as far as daily livestock feed production is concerned, it typically only gives a rough estimate for any particular day. On the days when demand was light, the workforce overproduced. Their work was stored as inventory and now if there is a day with very high demand that is beyond the capacity of the workforce, the inventory is there as a safety net against backorders. Helping to determine what they should be, can help cut back on unneeded inventory, and knowing what they are can help determine average warehouse usage, inventory risk, percentage of assets that are made up inventory, holding costs, etc (Panneerselvam, 2003).

Feed mill manager needs to evaluate holding costs, backorder costs, and feed demand. The most difficult problems to solve in connection with inventory of feed stuffs and finished feeds are the three areas i.e. excessive stock investment, inadequacy of stock to meet demand, and inaccuracy of stock records. This variability results from many different causes, none of which is dominant. Therefore, the variability can be explained by probability distributions. The set of all possible outcomes of an experiment is defined as a sample space, for all the chance of occurrences. On the basis of same concept sample space I to sample space V have been considered and summed up for discrete probability distribution for overall business analysis and economic feasibility (Sharma, 2000). Inventory models can be classified as either deterministic (variables are known with certainty) or stochastic modeling (variables are probabilistic) method (Adam and Ebert, 2003). Since to minimize the affect of uncertainty / variation, decision has to be taken, based on the DSS a computer software has been designed and developed for production and optimum perishable commodity inventory management of feed production plant / mill under stochastic modeling approach.

METHODOLOGY

The Decision Support System (DSS) computer software was designed and developed for production and optimum perishable commodity inventory management of feed production plant / mill under stochastic modeling approach. The flow chart for computer programme developed in C++ is given in Fig. 1. The computer programme was validated for small scale feed industry at CIAE feed plant assuming cost parameters for feed / ingredients as given in Table 1.

There were five sample spaces, reasonably considered in numbers for analysis of expected eventual demand of feed. Such events were categorized based on finished feed inventory probability grading A to E from excellent i.e. highest favourable feed demand to poorest anticipated demand i.e. least favourable feed demand affecting production environment. All these five events from A to E were mutually exclusive and collectively exhaustive. The set of all possible outcomes of an experiment was defined as sample space I to sample space V. The inventory of finished feed or stock of feed in a month was kept under falling stages i.e. most favorable event (A) = 3,000, next to most favorable (B) = 2,500, next to B was C = 2000, next to C was D = 1500 and poor or least favorable (E) = 1000). According to probability distribution pattern summing of all the probability of occurrence was done and then summing them up for analysis of discrete probability distribution. The more of favorable events or less of unfavorable events out of A to E (5) was taken into consideration in case of more variation of expected demand data. Accordingly, output resulted from application of DSS was tabulated (Table 2) and drawn in Fig. 2.

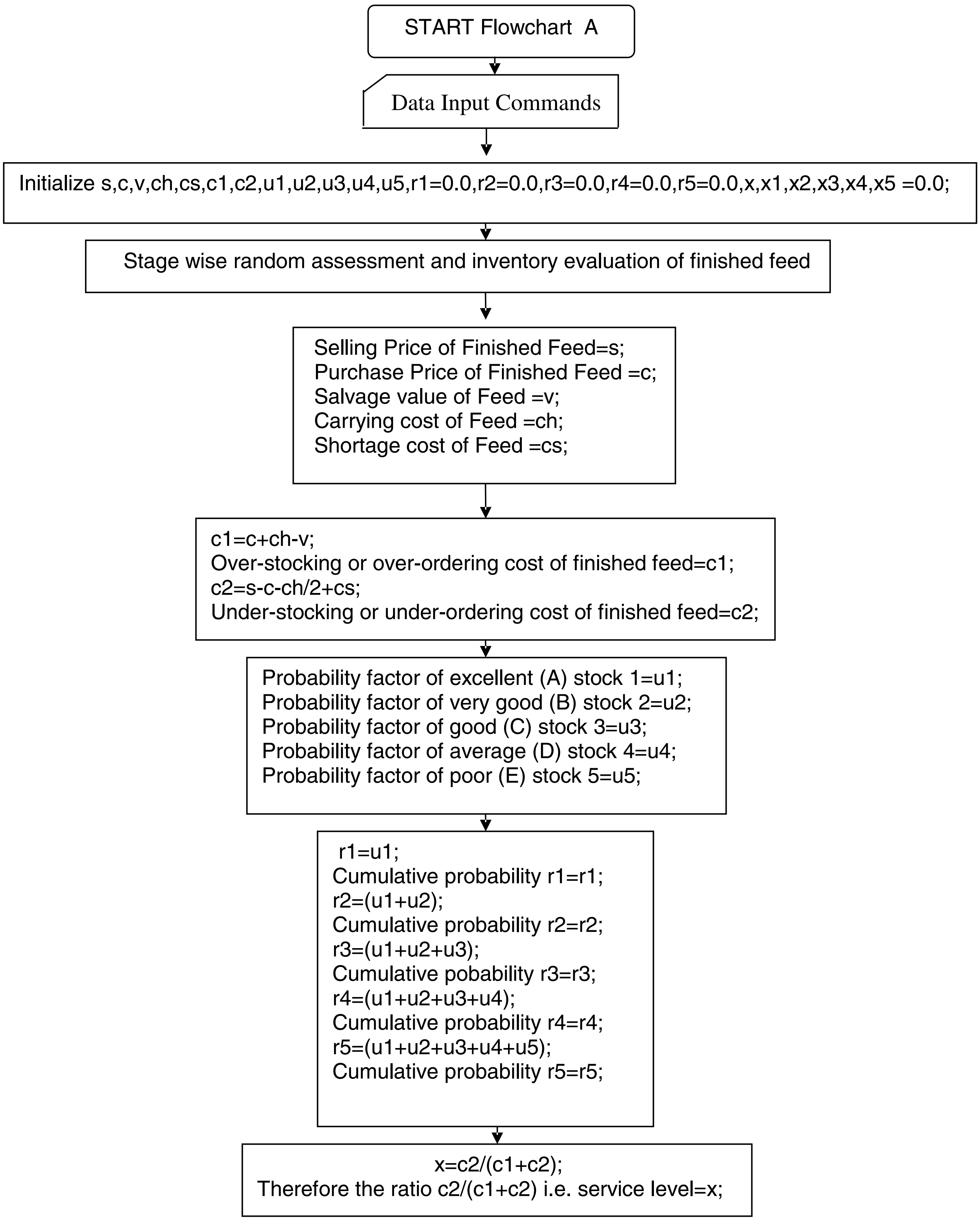
RESULTS AND DISCUSSION

Sample space I: The sample space I was described as the set of all happenings / occurrences with the maximum of best of favorable outcome (event A), wherein the discrete probability distribution was shared most of higher side of expected demand [probabilities of events A (excellent) = 0.5, B (very good) = 0.3, C (good) = 0.1, D (average or fair) = 0.05 and E (poor) = 0.05]. The sample space I, wherein maximum of favorable feed demand was expected. Such event is expected on most of the time positive circumstances or favorable environment prevail mostly in feed business. In such situations optimal feed stock may be kept to 2,350 q/month out of maximum capacity of 3,000 q per month (Table 2).

Sample space II: The sample space II was described as the set of events from A to E with the next of best of favorable outcome than that of sample space I, wherein the discrete probability distribution may be shared more of higher side of expected demand than that of sample space III but less than that of sample space I [probabilities of events A (excellent) = 0.3, B (very good) = 0.4, C (good) = 0.15, D (average or fair) = 0.10 and E (poor) = 0.05)]. Such set of events

Table 1: Assumptions / values based on cost parameters of finished feed / ingredients

S. No.	Particulars of Parameter of feed / ingredient	Value of Parameters (Rs./q)
01	Price of finished feed as cattle feed	1,500.00
02.	Price of raw ingredients	1,050.00
03	Salvage value of feed	1,000.00
04	Carrying cost of feed	100.00
05	Shortage cost of feed	350.00
06	Overstocking or over-ordering cost	150.00
07	Under stocking or under-ordering cost	750.00


START Flowchart A
Data Input Commands
Initialize s,c,v,ch,cs,c1,c2,u1,u2,u3,u4,u5,r1=0.0,r2=0.0,r3=0.0,r4=0.0,r5=0.0,x,x1,x2,x3,x4,x5 =0.0;
Stage wise random assessment and inventory evaluation of finished feed
Selling Price of Finished Feed=s;
Purchase Price of Finished Feed =c;
Salvage value of Feed =v;
Carrying cost of Feed =ch;
Shortage cost of Feed =cs;
c1=c+ch-v;
Over-stocking or over-ordering cost of finished feed=c1;
c2=s-c-ch/2+cs;
Under-stocking or under-ordering cost of finished feed=c2;
Probability factor of excellent (A) stock 1=u1;
Probability factor of very good (B) stock 2=u2;
Probability factor of good (C) stock 3=u3;
Probability factor of average (D) stock 4=u4;
Probability factor of poor (E) stock 5=u5;
r1=u1;
Cumulative probability r1=r1;
r2=(u1+u2);
Cumulative probability r2=r2;
r3=(u1+u2+u3);
Cumulative pobability r3=r3;
r4=(u1+u2+u3+u4);
Cumulative probability r4=r4;
r5=(u1+u2+u3+u4+u5);
Cumulative probability r5=r5;
x=c2/(c1+c2);
Therefore the ratio c2/(c1+c2) i.e. service level=x;

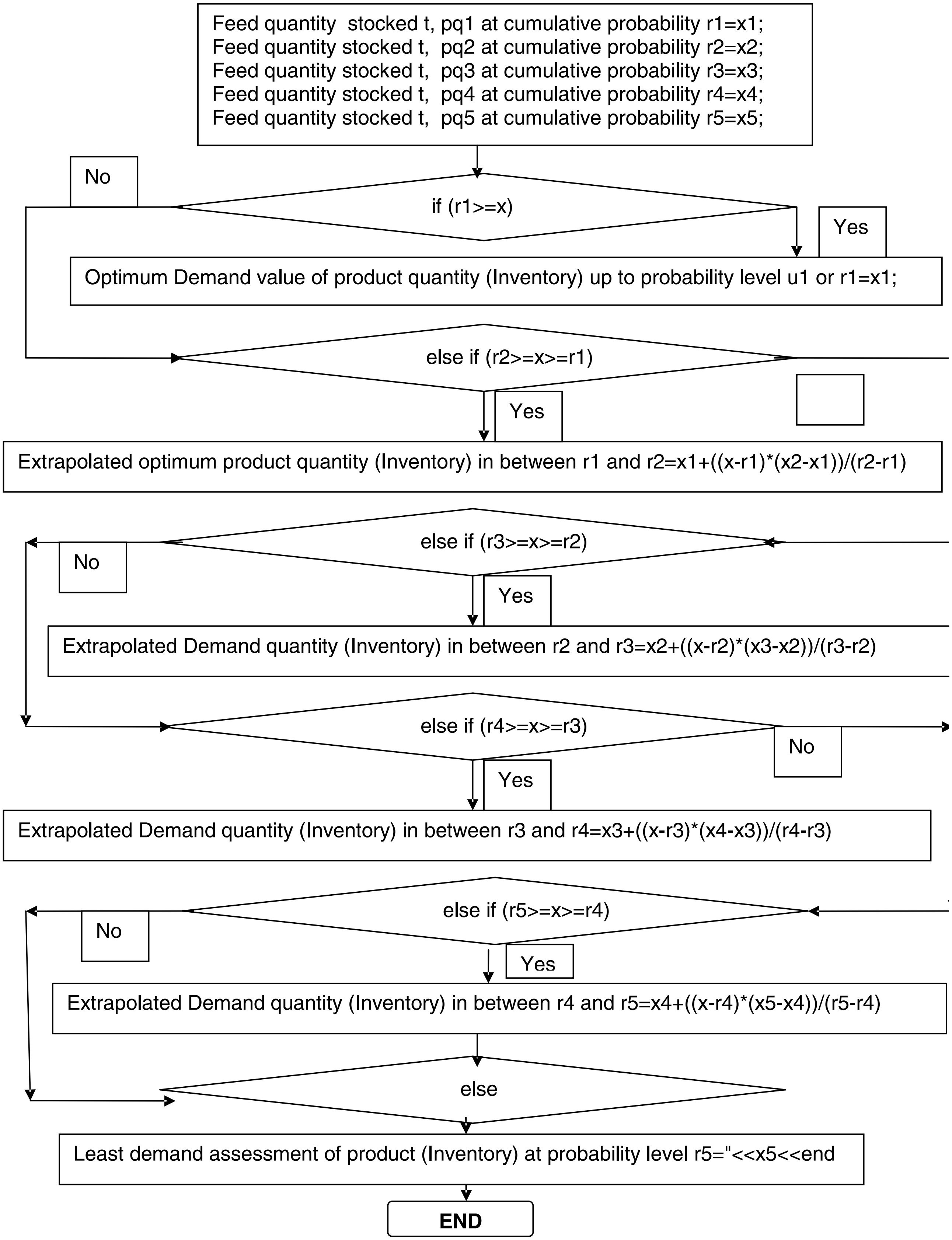


Fig. 1: Flow chart for determination of required finished feed inventory

Table 2: Variable demand vs. finished feed inventory stocking

Grade & Demand Status (with respect to quantity of stock) to be Stored		Discrete Probability Distribution Factor (Under Various Sample Spaces)				
Grade & Demand Status	Feed Stock (q) (Gradewise / Month)	Sample Space I	Sample Space II	Sample Space III	Sample Space IV	Sample Space V
Event A- Excellent	3,000	0.5	0.3	0.25	0.2	0.05
Event B- Very Good	2,500	0.3	0.4	0.2	0.2	0.15
Event C-Good	2,000	0.1	0.15	0.2	0.2	0.2
Event D-Average	1,500	0.05	0.10	0.25	0.2	0.2
Event E-Poor	1,000	0.05	0.05	0.1	0.2	0.4
Optimum quantity of finished feed stock (q) →		2,350	2,050	1,650	1,400	1,200

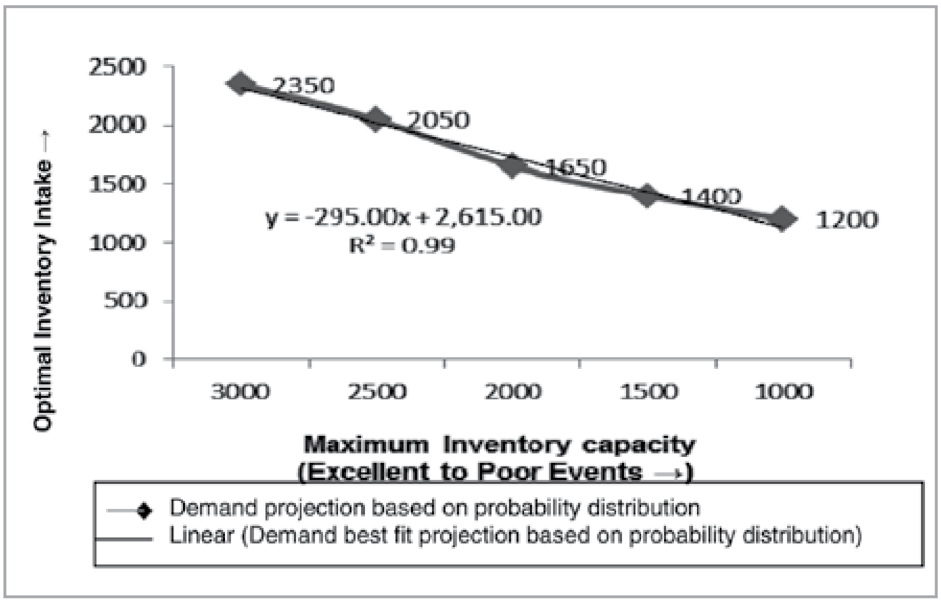


Fig. 2: Feed inventory projection on Discrete Probability Distribution (Events) basis

is expected to prevail on favorable chances of feed demand but competitor may become proactive and aggressive and somewhat less probable chance of inventory disposal. Here, optimal quantified feed stock may be 2,050 q/month out of maximum 3000 q per month.

Sample space III: The sample space III which was considered to be the set of events A to E, wherein higher side of shared demand more than that of sample space IV and less than that of sample space II (probabilities of events A (excellent) = 0.25, B (very good) = 0.2, C (good) = 0.2, D (average or fair) = 0.25 and E (poor) = 0.1) is anticipated to fall. Such sample space is expected, when competitor becomes more stable on account of more effective business game plan and start capturing major market share. In such situations optimal feed stock may be quantified to 1650 q per month out of maximum 3000 q/month.

Sample space IV: The sample space IV which was considered to be the chance, wherein higher side of shared demand more than that of sample space V and less than that of sample space III [probabilities of events A (excellent) = 0.2, B (very good) = 0.2 C (good) = 0.2, D (average or fair) = 0.2 and E (poor) = 0.2] is expected to fall. Such sample space IV is expected when not only competitors become very aggressive but also increase in cost of ingredients leads to hike in the price of finished feed affecting business prospects adversely. Here, optimal feed stock may be kept to quantity 1,400 q/month out of maximum favorable 3000 q per month.

Sample space V: The set of events V was described as the total happenings /chances with the least of possible outcome, wherein the discrete probability distribution may be shared with more of least anticipated demand [probabilities of events A (excellent) = 0.05, B (very good) = 0.15, C (good) = 0.2, D (average or fair) = 0.2 and E (poor) = 0.4]. In the sample space V, minimum of feed demand is expected. This has been such a sample space, when maximum of business prospects are diluted due to unfavorable circumstances looming over feed business sector, include the adverse effect caused due to off seasonality, wherein livestock farmers grow more green fodder and start manufacturing their own feed by setting up their own enterprise. Here, optimal feed stock may be stored as 1,200 q per month out of maximum 3000 q/month.

It is based on optimum inventory demand evaluation the best fitted equation was determined (y = - 295 x + 2615) with very high degree of correlation i.e. 0.99. The 'y' as response variable for optimization of inventory stock based on most likely probable chances was considered under demand of feed and x as independent variable considered for random value decided on the basis of raw value judgment from maximum expected demand i.e. most favorable (excellent) situation to least favorable demand i.e. poor situation for optimum perishable products inventory evaluation and feed stock management.

CONCLUSIONS

A Computerized programme was developed based on stochastic modeling, algorithm for comparative alternative arrangements for perishable products. This may be used as decision support system (DSS) for inventory management of finished feed for modern feed industries based on simulation technique. The DSS as a better representation of real life situation from economic angles and directly or indirectly may also cover social functional aspects for managing optimum finished feed inventory. Feed stock management is better replenished through convenience in optimum perishable material handling and minimization of holding cost may eventually be anticipated for cost reduction. An algorithm is given to derive the optimal solutions of the proposed models. The impact of the deterioration rate on the finished feed stock replenishment policies under the given operational flow chart eventually may become powerful tool for fresh and systematic feed stock management.

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Mechanization Indicating Parameters for Site Selection of Farm Machine Bank in Bihar

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ABSTRACT

In Bihar, mechanization among small and marginal farmers has always been a big challenge. Mechanization in community mode targeting small and marginal farmers may be easily done through constitution of farm machine bank. But the main challenge is to find out a proper site for establishment of bank at village, block or district level so that majority of farmers may reach easily there and hire the machine that will give maximum profit. Under present study, two blocks from each four districts namly Darbhanga, Madhubani, Muzaffarpur and Sitamarhi in Bihar were considered for finding out a particular block for establishment of farm machine bank. Mechanization indicating parameters such as status of mechanization, cropping intensity, annual agricultural income of farmers, farmers' choice for co-operative mechanization, power source (tractor) availability and tractor use pattern etc were accorded. The site for farm machine bank was found out through process of optimization of indicators. In Darbhanga, Madhubani, Muzaffarpur and Sitamarhi districts Benipur, Madhwapur, Sakra and Dumra blocks respectively were selected having cumulative qualitative grade A^4B^2 as compared to their counterpart blocks.

Key words: *Mechanization, Farm machine bank, Custom hiring, Cumulative qualitative grade, Community mode*

INTRODUCTION

Indian agriculture needs timeliness in operation, optimization of critical inputs for increased production through introduction of mechanization. Strong need for mechanization was felt not only for large farmers but for small and marginal farmers too, in a number of studies conducted by researchers (Roy and Benzbaruah, 2002; Ghosh, 2009). Of course, the biggest challenge is to make agriculture profitable for small farmers having fragmented holdings. Under such situation, custom hiring of farm machines has been found as the effective solution (Sharma *et al.,* 2000; Anonymous, 2002; Foster and Rosenzweig, 2010; Jayaram, 2012).

In Bihar, majority of farmers cannot afford purchase of costly machines in spite of demand due to their poor socio-economic condition. The costly machines with lower annual use do not fetch economy. Obviously, economical use of machines can only be realized their use for longer hours by way of custom hiring. In present mode of custom hiring, economically sound farmers purchase machine for self cultivation as well as its use in the fields of other farmers. Here machine owners give preference to the influencing farmers of the society who can offer the machine owner a large work. Secondly, even the users of machine remain completely unaware with the new technologies, functioning of machines, the required safety measures and maintenance issues. Thus, the mechanization brought about by existing custom hiring process cannot be sustainable and long lasting. Obviously, we need the custom hiring methods which may address major section of farming community, ensuring minimum investment by them and capable to educate them about different issues related to mechanization. Mechanization in participatory mode by establishment of Farm Machine Bank in villages can be the best alternative. Before establishment of bank, it is essential to decide its proper site so that benefits of mechanization may reach to majority of farmers. Therefore, the present investigation was planned with an objective to develop the methodology for selection of site of farm machine bank through optimization of different mechanization indicating parameters.

MATERIALS AND METHODS

Farm Machine Bank generally refers to an organization constituted under group ownership and run by a group of farmers on participatory basis with capital share between government and farmers in the ratio of 70:30 percent and where site and situation specific need based farm machines are purchased for their operation on custom hiring basis in the fields of member farmers as well as other non-member farmers. The aim remains to promote mechanization at grass root level in most economical way besides knowledge and skill generation amongst the farming community. Farm mechanization in Darbhanga, Madhubani, Sitamarhi and Muzaffarpur districts is still very low. Therefore, it was decided to identify the aforesaid districts as domain of research under the present investigation. For pilot study, two blocks of each of the four districts situated nearby and easily accessible by road from district headquarter were selected for survey with the consent of local District Agriculture Officer for deciding location of bank in one of the most appropriate block based on different criteria affecting mechanization process.

The selection of specific block for establishment of Farm Machine Bank was done based on parameters such as status of mechanization, cropping intensity, agricultural income of farmers, choice for self-owning the machine/ cooperative mechanization, power source availability, tractor use pattern etc. These parameters, based on their importance, were provided priority grade as **more priority area** and **less priority area**. More priority area was given qualitative grade **'A'** whereas the less priority area, as qualitative grade **'B'** (Table 1). Data generated from survey in two blocks of each district with respect to mechanization indicating parameters was compiled in tabular form. The block dominating with qualitative grade 'A' was accorded priority for establishment of Farm Machine Bank over other block of the same district having more dominant with qualitative grade 'B'.

Determination of mechanization indicating parameters: Under present study, more priority was given to the block having lower status/level of mechanization and vice-versa as under such situation there remains more opportunity of use of machines on custom hiring basis. The number of farm families and number of mechanized farm families for all selected villages in a particular block was found out by survey. The status of mechanization in percentage was then calculated for each block by using the formula:

Table 1: Prioritization and grading of mechanization indicators for selection of specific block for establishment of Farm Machine Bank.

S. No.	Parameters	Indicators for selection of Farm Machine Bank	
		More priority–grade 'A'	**Less priority –grade 'B'**
1.	Status of mechanization	Lower mechanized area	Higher mechanized area
2.	Cropping intensity	Higher cropping intensity	Lower cropping intensity
3.	Annual agricultural Income of farmers	Higher income group farmers	Lower income group farmers
4.	Choice for self-owning the machine/ cooperative mechanization	More choice for cooperative farming	Less choice for cooperative farming
5.	Power source availability	Higher percentage of available power source	Lower percentage of available power source
6.	Tractor use pattern	Higher custom hiring period	Lower custom hiring period

$$\text{Status of mechanization (\%)} = \frac{\text{No. of mechanized farm family}}{\text{No. of farm families}} \times 100$$

Cropping intensity: The cropping intensity is the indicator of the growth of agriculture. The priority for selection of site was given to the block having higher cropping intensity over other block with lower cropping intensity. The cropping intensity was calculated by using the formula:

$$\text{Cropping intensity (\%)} = \frac{\text{Gross cropped area}}{\text{Net cultivable area}} \times 100$$

Annual agricultural income of farmers: The investment capacity of farmers has a direct correlation with their annual income from agriculture and other sources. Under present study income from agriculture was taken into account. With the above consideration, priority in selection of site for Farm Machine Bank was given to the block with average higher annual agricultural income of farmers as compared to the block with farmers having lower average annual agricultural income.

Choice for self-owning the machine/ cooperative mechanization: The Farm Machine Bank is the forum, where mechanization is to be promoted in community mode with cooperation of the member farmers. Obviously, the attitude and choice of the farmers to work together as a group will be a deciding factor in establishment of Farm Machine Bank and accordingly, priority for selection of site for machine bank was given to the block with maximum choice level of farmers for cooperative mechanization in form of Farm Machine Bank. The machines selected for the bank must be of high working capacity as they are to be operated on custom hiring basis. Such machines will be exclusively tractor drawn as the power requirement for commercial model of such machines will be high. Obviously, the area where tractor availability percentage is high, there will be enough scope of use of machines by the farmers on custom hiring basis. Accordingly, priority to site for establishment of bank was accorded to the block with higher population of tractors over the other block. The area where the use of tractor on custom hiring was more as compared to the area where tractors are mostly used for self cultivation will have more opportunity for use of machines of bank by the farmers. Based on above facts, priority in selection of site for machine bank was accorded to the block where tractors have maximum use on custom hiring than the block where its use on this side was comparatively low.

The data emerged from the survey conducted in two blocks of each identified district were compiled and analysed. The observations recorded regarding status of mechanization, cropping intensity, annual agricultural income of farmers, choice of farmers for cooperative mechanization, power source availability, tractor use pattern etc. have been discussed in detail to reach upon a final conclusion regarding suitability of site for establishment of Farm Machine Bank through the process of optimization of priority levels of these indicators.

RESULTS AND DISCUSSION

It is apparent from Table 2 that the minimum

Table 2: Status of farm mechanization in selected blocks of identified districts

S. No.	District	Block	Number of villages	Number of farm families	No. of mechanized farm family	Status of mechanization (%)
1.	Darbhanga	Benipur	11	1956	94	4.81
		Alinagar	18	2096	83	3.96
2.	Madhubani	Benipatti	8	3557	517	14.53
		Madhwapur	8	3048	335	10.99
3.	Muzaffarpur	Sakara	18	2979	119	3.99
		Muraul	8	1410	137	9.72
4.	Sitamarhi	Dumara	8	1350	68	5.04
		Runni Saidpur	8	1040	118	11.35

percentage of mechanization level in Darbhanga district was in Alinagar Block (3.96%) followed by Benipur (4.81%). Similarly in Madhubani district, the mechanization level was maximum in Benipatti block (14.53%) and minimum in Madhwapur block (10.99%). In Muzaffarpur and Sitamarhi, minimum mechanization level was in Sakara (3.99%) and Dumara block (5.04%) followed by Muraul (9.72%) and Runni Saidpur (11.35%) respectively. Between two blocks of the same districts, the variation in mechanization percentage may be due to the fact that villages selected for survey in the blocks with higher percentage of mechanization were nearer to the block headquarter. Therefore, the people of these villages have got the maximum benefit of subsidy programme on mechanization because of greater awareness about the Government supported programmes.

Upon comparison of average cropping intensity between two blocks of a particular district, it was found that Alinagar, Benipatti, Muraul and Dumara blocks of Darbhanga, Madhubani, Muzaffarpur and Sitamarhi districts, had higher cropping intensity than their counterpart blocks (Table 3). However, there was not much variation in cropping intensity in different selected blocks of identified district except the Runni Saidpur. The minimum cropping intensity in Runni Saidpur block (148.83%) of Sitamarhi district due to devastating flood in adjoining Bagmati River and water remains inundated in large area and thus, transplanting of rice and sowing of wheat gets affected.

It is evident from Table 4 that farmers of Sakara block of Muzaffarpur district had highest average annual agricultural income i.e. Rs. 99,306.00 followed by farmers of Dumara block of Sitamarhi district i.e. Rs. 89,375.00. The farmers of Benipatti block of Madhubani district registered lowest average annual agricultural income i.e. Rs. 32,094.00 followed by farmers of Madhwapur block of the same district with average annual agricultural income Rs. 34,344.00.

Table 3: Cropping intensity in selected blocks of identified districts

S. No.	District	Block	No. of villages	No. of sample farmers	Av. Cropping intensity (%)	Av. Percentage land utilization under different crops			
						Rice	Wheat	Maize	Others
1.	Darbhanga	Benipur	11	30	170.95	76.41	58.98	-	35.56
		Alinagar	18	30	185.61	80.79	63.63	9.98	31.21
2.	Madhubani	Benipatti	8	32	169.48	70.31	37.5	17.13	44.54
		Madhwapur	8	32	162.38	67.18	41.20	2.23	51.77
3.	Muzaffarpur	Sakara	18	32	166.98	51.81	61.81	18.47	34.89
		Muraul	8	32	177.45	53.07	45.87	19.65	58.86
4.	Sitamarhi	Dumara	8	32	177.56	59.23	47.53	16.14	54.66
		Runni Saidpur	8	32	148.83	53.71	41.35	11.45	42.32

Table 4: Average annual agricultural income of farmers in selected blocks of identified districts

S. No.	District	Block	Number of villages	Number of sample farmers	Average annual agricultural income of farmers (Rs.)
1.	Darbhanga	Benipur	11	30	49712.00
		Alinagar	18	30	36463.00
2.	Madhubani	Benipatti	8	32	32094.00
		Madhwapur	8	32	34344.00
3.	Muzaffarpur	Sakara	18	32	99306.00
		Muraul	8	32	73906.00
4.	Sitamarhi	Dumara	8	32	89375.00
		Runni Saidpur	8	32	54281.00

In Darbhanga district, farmers of Benipur block had higher annual agricultural income (Rs. 49,712.00) than farmers of Alinagar block (Rs. 36,463.00). The higher annual agricultural income of farmers of Sakara and Dumara blocks was due to cultivation of maize, potato, sugarcane and other vegetable and cash crops which are more remunerative than the rice and wheat crop. The connectivity of the block from the town by good roads also appeared to be a significant factor for the average annual agricultural income of farmers as they had greater opportunity to sale their produce at higher price in the market.

The data presented in Table 5 clearly shows that farmers had more choice for cooperative mechanization in Benipur, Madhwapur, Dumara and Sakara blocks of Darbhanga, Madhubani, Sitamarhi and Muzaffarpur districts. Although, between two selected blocks of the same districts, there was not much variation in choice for cooperative farming but, at all places the choice for cooperative farming was found dominating over other choices i.e. self-owning of machines on subsidy or the farmer's choice for continuation of both the system. The higher choice of farmers at all places for cooperative mechanization was for mechanization of all farm operations.

The maximum tractor availability was in Benipatti and Runni Saidpur blocks of Madhubani and Sitamarhi districts respectively (Table 6). It was minimum in Benipur and Alinagar blocks of Darbhanga district and Madhwapur block of Madhubani district. In

Table 5: Farmer's choice for cooperative mechanization in selected blocks of identified districts

S. No.	District	Block	No. of villages	No. of sample farmers	Choice for different mechanization mode		
					Cooperative mechanization in form of Farm Machine Bank	Self owning of machines on subsidy basis	Both
1.	Darbhanga	Benipur	11	30	77.42	7.12	15.46
		Alinagar	18	30	61.11	12.96	25.93
2.	Madhubani	Benipatti	8	32	62.50	18.75	18.75
		Madhwapur	8	32	71.88	6.25	21.87
3.	Muzaffarpur	Sakara	18	32	70.37	12.50	17.13
		Muraul	8	32	65.62	15.63	18.75
4.	Sitamarhi	Dumara	8	32	71.87	12.50	15.63
		Runni Saidpur	8	32	62.50	15.63	21.87

Table 6: Power source (tractor availability) in different power ranges in selected blocks of identified districts

S. No.	District	Block	No. of villages	No. of sample farmer	No. of tractors	Distribution of tractor according to power range, (%)			
						Less than 30hp	30-35 hp	36-40 hp	Above 40hp
1.	Darbhanga	Benipur	11	30	30	20.00	66.67	10.00	3.33
		Alinagar	18	30	30	23.33	36.67	33.33	6.67
2.	Madhubani	Benipatti	8	32	35	14.29	74.29	11.42	0.00
		Madhwapur	8	32	30	36.66	56.67	0.00	6.67
3.	Muzaffarpur	Sakara	18	32	33	3.03	63.64	12.12	21.21
		Muraul	8	32	31	0.00	70.97	25.81	3.22
4.	Sitamarhi	Dumara	8	32	31	3.23	61.29	22.58	12.90
		Runni Saidpur	8	32	35	5.71	40.00	28.57	25.72

Muzaffarpur, tractor population in Sakara block was more than that in Muraul block. In Sitamarhi district, tractor population was much lower in Dumara block than Runni Saidpur block.

The data collected with regards to use of tractor for self cultivation by the farmers and also its use on custom hiring is presented in Table 7. In Sitamarhi district, tractor use on custom hiring was more in Runni Saidpur block (723 h) than Dumara block (462 h). In Muzaffarpur, tractor use on custom hiring was 326 h in Muraul block than 302 h in Sakara block. Similarly, in Darbhanga and Madhubani districts, Benipur (332 h) and Madhwapur (150 h) registered higher tractor use on custom hiring than their counterpart blocks Alinagar (286 h) and Benipatti (135 h).

Based on the indicators and their grading, optimization process was adopted to decide the suitability of

Table 7: Tractor use pattern in different blocks of identified districts

S. No.	District	Block	No. of villages	No. of sample farmer	No. of tractors	Tractor density/ farmer	Annual use pattern of tractor (hour)		
							Self cultivation	Renting/ custom hiring	Total use
1.	Darbhanga	Benipur	11	30	30	1.00	275	332	607
		Alinagar	18	30	30	1.00	229	286	515
2.	Madhubani	Benipatti	8	32	35	1.09	56	135	191
		Madhwapur	8	32	30	0.94	67	150	217
3.	Muzaffarpur	Sakara	18	32	33	1.03	206	302	508
		Muraul	8	32	31	0.97	143	326	469
4.	Sitamarhi	Dumara	8	32	31	0.97	231	462	693
		Runni Saidpur	8	32	35	1.09	113	723	836

Table 8: Optimization of different indicators and selection of specific block for establishment of Farm Machine Bank

S. No.	Parameters	Qualitative grade* for different sites in identified districts							
		Madhubani		Darbhanga		Muzaffarpur		Sitamarhi	
		Benipatti	Madhwapur	Benipur	Alinagar	Sakara	Muraul	Runni Saidpur	Dumara
1.	Status of mechanization	B	A	B	A	A	B	B	A
2.	Cropping intensity	A	B	B	A	B	A	B	A
3.	Annual agricultural income of farmers	B	A	A	B	A	B	B	A
4.	Choice of farmers for cooperative mechanization	B	A	A	B	A	B	B	A
5.	Power source availability	A	B	A	A	A	B	A	B
6.	Tractor use pattern	B	A	A	B	B	A	A	B
7.	Cumulative grade	A^2B^4	A^4B^2	A^4B^2	A^3B^3	A^4B^2	A^2B^4	A^2B^4	A^4B^2

**Qualitative Grade: More priority – A; Less priority – B* specific block for establishment of Farm Machine Bank. The cumulative grading of different indicators was done and presented in Table 8. It was evident from Table 8 that Madhwapur block dominated in priority grade 'A' over Benipatti block in Madhubani district. Similarly, in Darbhanga, Muzaffarpur and Sitamarhi districts; Benipur, Sakara and Dumara blocks dominated in overall priority grade 'A' as compared to their counterpart blocks of the same district. Thus, through optimization process of different indicators, Madhwapur, Benipur, Sakara and Dumara blocks were selected for establishment of Farm Machine Bank in Madhubani, Darbhanga, Muzaffarpur and Sitamarhi district respectively.

CONCLUSION

Upon adopting process of optimization of different indicators of mechanization, it was found that Madhwapur, Benipur, Sakra and Dumra block of Madhubani, Darbhanga, Muzaffarpur and Sitamarhi districts respectively had qualitative cumulative grade A^4B^2. Obviously, they were dominating with qualitative grade 'A' (more priority) as compared to their counterpart blocks of the aforesaid districts that were dominating with qualitative grade 'B' (less priority). Selection of specific block for establishment of farm machine bank was done with maximum weightage to qualitative grade 'A' and accordingly Madhawapur, Benipur, Sakra and Dumra Block of Madhubani, Darbhanga, Muzaffarpur and Sitamarhi districts were selected for establishment of Farm machine bank under the present study.

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Effect of Operating Parameters on Decortication of Jatropha Curcas L. Fruits

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ABSTRACT

Jatropha curcas L. is a multipurpose shrub or tree with immense medicinal and industrial values. Manual decortication of the fruits to extract seeds is uneconomical, time consuming, associated with drudgery and low output capacity. The tractor operated castor decorticator was modified for decortication of jatropha fruits and assessed for performance evaluation. The studies on jatropha decorticator were conducted with three parameters i.e. effect of moisture content (7.95, 9.05 and 12.84 % d.b.), cylinder speed (1.38, 1.57, 1.78 and 1.97 m/s) and concave clearance (16 and 18 mm) at feed rate of 6 kg/min. The performance was evaluated for its decortication efficiency, cleaning efficiency, percentage seed loss, mechanical damage and output capacity at different combination of operating parameters. The optimum combination of parameter was found as 9.05 per cent moisture content (d.b.), 1.97 m/s cylinder speed and 16 mm concave clearance with output capacity of 210.57 kg/h. The performance of this decorticator has indicated the possibility of exploiting the full industrial potential of jatropha fruits.

Key words: *Jatropha fruit; Moisture content; Decortication efficiency; Cylinder speed.*

INTRODUCTION

The vibrancy of economy of a country is indicated by its energy consumption. Oil and gas continues to play an important role in meeting the world energy requirement. Ever since the discovery of this black gold, there has been a consistent increase in its demand. In various countries different vegetable oils are used for biodiesel production. The United States is one of the major exporter of edible oils hence it uses soyabean oil as a raw material for biodiesel production. Rapeseed oil is in use in European countries for biodiesel production whereas tropical countries such as Malaysia use coconut oil or palm oil for the purpose. India is a net importer of edible oil, hence the emphasis is on non-edible oils from plants such as jatropha, karanja, neem, mahua, etc which could be utilized as a source for production of oil. The large scale production of bio-diesel in India is possible from jatropha, an oilseed bearing tree which is non-edible and widely accepted as a potential agricultural solution for subtropical and tropical locations. Biodiesel, an alternative fuel, is technically feasible, economically competitive and environmentally acceptable and can be made readily available. Among bio-fuels, bio-diesel is gaining worldwide acceptance as a solution as diesel fuel extender.

Jatropha curcas is a species of flowering plant in the spurge family, Euphorbiaceae. It is cultivated in tropical and subtropical regions around the world, becoming naturalized in some areas for erosion control. Estimate shows that one hectare of land produces 2.5 tonnes of oil, that's four times more than soybean and 10 times more than corn. 20,000 hectares is an equivalent of 3 megawatt station feeding power to 5,000 homes. The productive lifespan of Jatropha can be 20-30 years. Jatropha starts to produce fruit after 1-2 years and the productivity will become stable after the plant is 4-5 years old.

In India flowering of jatropha occurs in warm rainy season. The peak period for flowering is July to August and fruits bear between September and December. The hull or shell of mature fruit becomes hard and black in colour. The dry fruits remain on the branches and contain 2-3 seeds. The decorticated seed give maximum oil yield in comparison to un-decorticated seeds. The oil content of Jatropha seed ranges from 27-40 per cent by weight (Achten *et al.* 2008). The decorticating of Jatropha fruits means breaking and complete removal of the seed coat/shell and taking out the seed without causing damage for oil expression. Traditionally, decortication of jatropha fruits involves collection of harvested fruits, drying and beating of these dried fruits with sticks/stones for separating seeds from fruits, then cleaning it by manual winnowing. This manual decorticating process is tedious, time consuming and labour intensive and thus it indulges drudgery in the system. Therefore, a castor decorticator was modified as physical characteristics of castor seed matches with jatropha and can be used for jatropha fruit decortication. The study was made on machine-crop parameter to evaluate the performance evaluation.

MATERIALS AND METHODS

The crushing cylinder of castor decorticator was modified such that the outer diameter was 250 mm and 580 mm in length, made from 50 mm thick M.S. rings for jatropha decortication. Three shoe plates 50 mm thick, having three numbers of 10×10 mm square bars each were mounted on the ring and the whole unit was mounted on 30 mm diameter shaft (Fig. 1). The concave was made of square M.S. bars of 5×5 mm size and 580 mm length which had perforation of 13 mm with 483 mm radial length (Fig. 2). Two sieves were used for separating fruit shell from seed having 15 mm and 12 mm hole diameter for 600×520 mm and 700×200 mm size respectively.

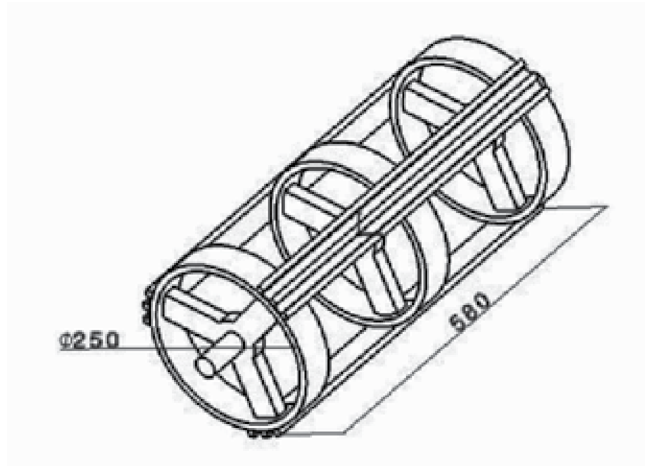

Fig. 1: Crushing cylinder

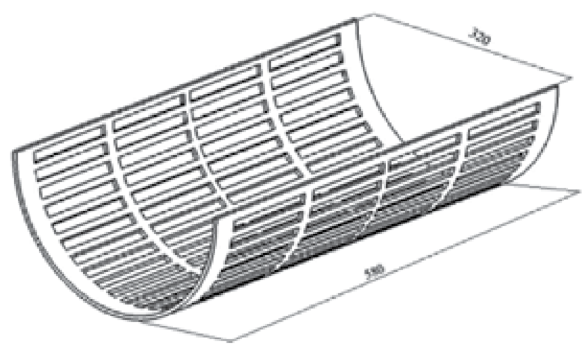

Fig. 2: Concave

The mature (black colour) jatropha fruits were procured by hand-picking from trees and gathered in bulk from the Soil and Water Conservation Research and Demonstration Farm, College of Technology and Engineering, Udaipur in December 2011. The total sample used for the project was divided into three equal batches and were sun dried to maintain three desired levels of moisture content. The initial moisture content was determined by using the hot air oven method (Gupta and Das, 1997). The sample was kept at 105±1° C for 24 h in an oven and final weight was noted. This three levels of moisture content were selected due to the fact that the moisture content of fruits may vary according to varieties, place, season, conditioning of fruit, etc at the time of processing operation. The fruit parts were carefully collected after going through the decorticating chamber and grouped into five category, namely fruits fully shelled (whole clean seed), damaged seed at all outlet, unshelled fruit at all outlet, chaff or foreign material at seed outlet, and seeds (whole, damaged and unthreshed) at chaff outlet. The variables taken for experiments were moisture content (M_1 = 7.95%, M_2 = 9.05%, M_3 = 12.84% db; cylinder speed (S_1 = 1.38 m/s, S_2 = 1.57 m/s, S_3 = 1.78 m/s, S_4 = 1.97 m/s) and concave clearance (C_1 = 16 mm, C_2 = 18 mm). Each treatment was replicated three times containing different set of combination of decortication parameters.

The various performance indices used for testing the jatropha decorticator were decortication efficiency, cleaning efficiency, percentage seed loss, mechanical damage and output capacity. The following expressions were used from the BIS Test code (2002) for calculation of different performance parameters:

i) Decortication efficiency = [1- C/Wt] ×100

ii) Cleaning efficiency = (A/A+D) × 100

iii) Percentage seed loss = (E/Wt) × 100

iv) Mechanical damage = (B/Wt) × 100

v) Output capacity = (A/t)

Where,

A= Fruits fully shelled (whole clean seed), g;

B= Damaged seed at all outlet, g;

C= Unshelled fruit at all outlet, g;

D= Chaff or foreign material at seed outlet, g;

E= Seed (whole, damaged and unthreshed) collected at chaff outlet, g;

Wt= Total weight of fruits feed into machine, g and

t= time requirement in min

The result obtained from 3×4×2 factorial experiment was analyzed. Analysis of variance (ANOVA) in completely randomize design was conducted for each of these performance indices with SPSS statistical software version 16.0.

RESULTS AND DISCUSSION

Decortications efficiency: The statistical analysis of the data for decortication efficiency revealed that moisture content, cylinder speed and concave clearance were found significant at 1 per cent level of significance. The interaction effect of moisture content with cylinder speed; moisture content with concave clearance and cylinder speed with concave clearance were also found significant at 1 per cent level of significance. It can be deduced from Fig. 3 that increase in the cylinder speed resulted in increase in decortication efficiency for different moisture content level. This may be due to the fact that at higher speed, the energy impacted on the fruits increases causing higher decortication efficiency. The highest average decortication efficiency was observed as 98.8 per cent. The decortication efficiency was favoured by high cylinder speed, low moisture content and low concave clearance. This result was found in the same trend as the results obtained by Chukwu (2008) and Pradhan *et al.* (2010).

Cleaning efficiency: The analysis of variance for the cleaning efficiency revealed that the moisture content; cylinder speed; concave clearance; the interaction of cylinder speed and concave clearance and three way interaction of moisture content, cylinder speed and concave clearance were found significant at 1 per cent level of significance. The cleaning efficiency of jatropha decorticator mostly depends on the blower speed and sieve shaking

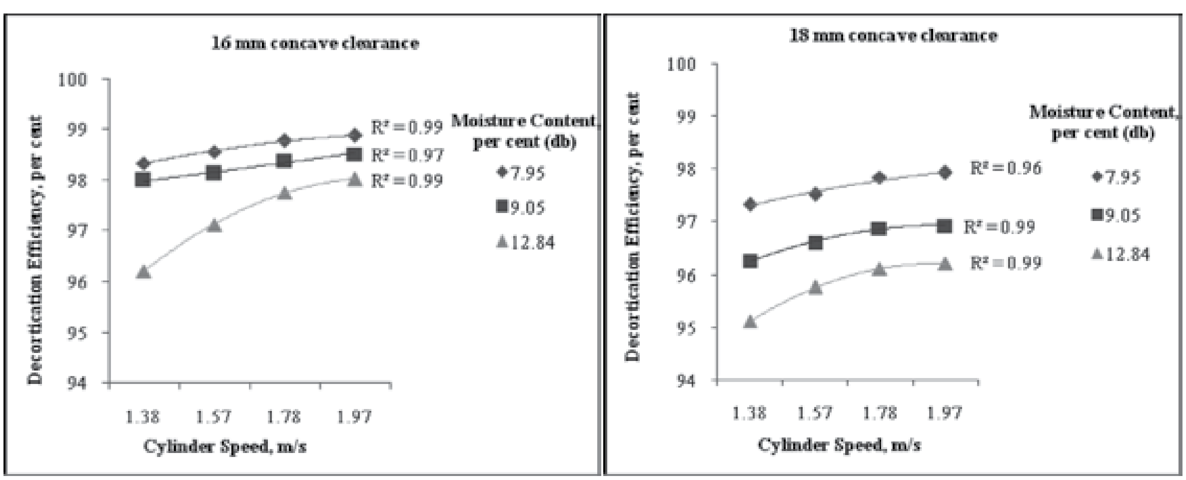

Fig. 3: Effect of cylinder speed and moisture content on decortication efficiency at different concave clearances

mechanism. The various levels of blower speed and sieve shaking mechanism were corresponds with the cylinder speed. Fig. 4 indicates that the cleaning efficiency increased with increase in cylinder speed significantly from 1.38 to 1.78 m/s then increased with reduced rate because at the higher cylinder speed blower speed also increased losing seed from chaff outlet which reduced cleaning efficiency. It was observed that cleaning efficiency ranged from 94.68 to 97.54 per cent and maximum of 97.54 per cent cleaning efficiency was recorded at moisture content of 7.95 per cent (d.b.), 1.97 m/s of cylinder speed i.e. 13.79 m/s of blower speed, and concave clearance of 18 mm. These findings are in accordance with Hamada *et al*. (2008) who reported similar result for sunflower thresher.

Percentage seed loss: The analysis of variables for the percentage seed loss showed that moisture content; cylinder speed; concave clearance; the interaction of moisture content with cylinder speed; interaction of moisture content with concave clearance were found significant at 1 per cent level of significance . It can be concluded from Table 1 that the percentage seed loss increased as the cylinder speed increased for all moisture content levels. The lowest achievable percentage of seed loss was found as 1.07 per cent at the cylinder speed of 1.38 m/s, 7.95 per cent moisture content (d.b.) and 18 mm concave clearance. This higher loss of seed was due to higher velocity of blower giving more air draft to lift the seed and husk from the surface of sieve thus causing the seed to be blown away along with husk. Similar results were also observed by Raji and Akaaimo (2005) and Kushwaha *et al.* (2005).

Mechanical damage: The analysis of variance for the mechanical damage showed that moisture

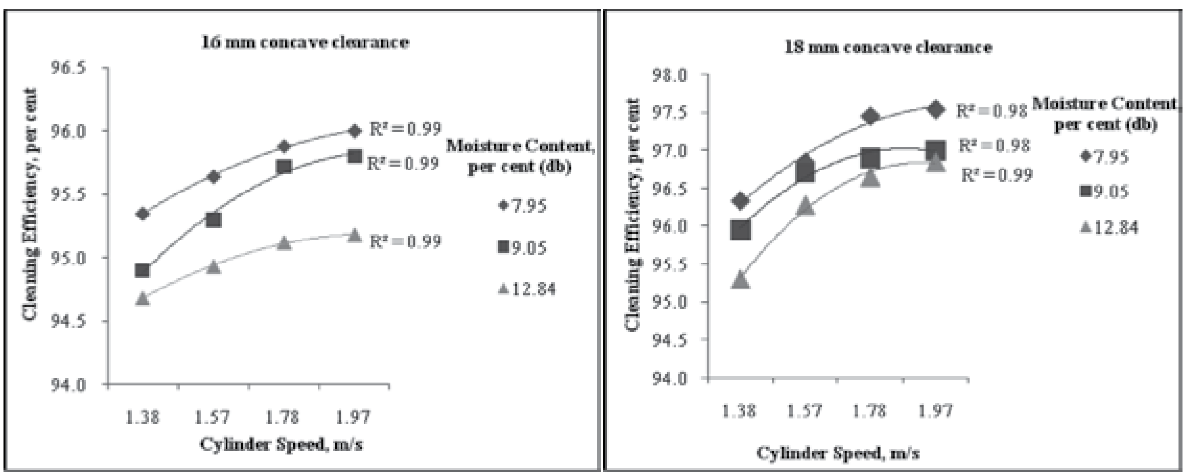

Fig. 4: Effect of cylinder speed and moisture content on cleaning efficiency at different concave clearances

Table 1: Mean value table for three variable interaction effects of moisture content, cylinder speed and concave clearance on percentage seed loss

Moisture content, per cent (d. b.)	Concave clearance, mm	Percentage seed loss, per cent			
		Cylinder speed, m/s			
		1.38	1.57	1.78	1.97
7.95	16	3.56	3.89	4.31	4.97
	18	2.82	3.22	3.54	4.25
9.05	16	2.50	2.75	3.45	4.06
	18	1.93	2.35	2.80	3.49
12.84	16	1.45	1.97	2.65	3.17
	18	1.07	1.78	2.25	3.02

content; cylinder speed; concave clearance and the interaction of moisture content with cylinder speed; moisture content with concave clearance and cylinder speed with concave clearance were found significant at 1 per cent level of significance (Table 2). The lowest value of mechanical damage was 2.39 per cent obtained at higher cylinder speed in combination of highest moisture content level and concave clearance. However, the lower moisture content of 7.95 per cent (db) resulted in general higher mechanical damage. The trend of this result was found similar to that observed by Tajudeen *et al.* (2005).

Output capacity: The statistical analysis of the data for output capacity revealed that moisture content, cylinder speed and concave clearance were found significant at 1 per cent level of significance. The interaction effect of moisture content with cylinder speed; moisture content with concave clearance and cylinder speed with concave clearance were also found significant at 1 per cent level of significance. It can be deduced from Fig. 5 that the increase in the cylinder speed resulted increase in output capacity. This may be due to the fact that at higher speed, the energy impacted on the fruits increased causing higher output capacity. The highest average output capacity was observed as 220.63 kg/h. This result was found as obtained by Chukwu (2008) and Pradhan *et al.* (2010).

CONCLUSIONS

The results of the performance evaluation of jatropha decorticator for moisture content range of 7.95 per cent to 12.84 per cent (d.b.), cylinder speeds of 1.38 m/s to 1.97 m/s and 16 mm and 18 mm concave clearance showed that decortication

Table 2: Mean value table for three variable interaction effects of moisture content, cylinder speed and concave clearance on mechanical damage

Moisture content, per cent (d. b.)	Concave clearance, mm	Mechanical damage, per cent			
		Cylinder speed, m/s			
		1.38	1.57	1.78	1.97
7.95	16	4.87	4.75	4.63	4.27
	18	3.82	3.58	3.55	3.07
9.05	16	4.18	3.94	3.63	3.37
	18	3.24	3.04	2.92	2.67
12.84	16	3.59	3.07	2.97	2.54
	18	2.77	2.63	2.54	2.39

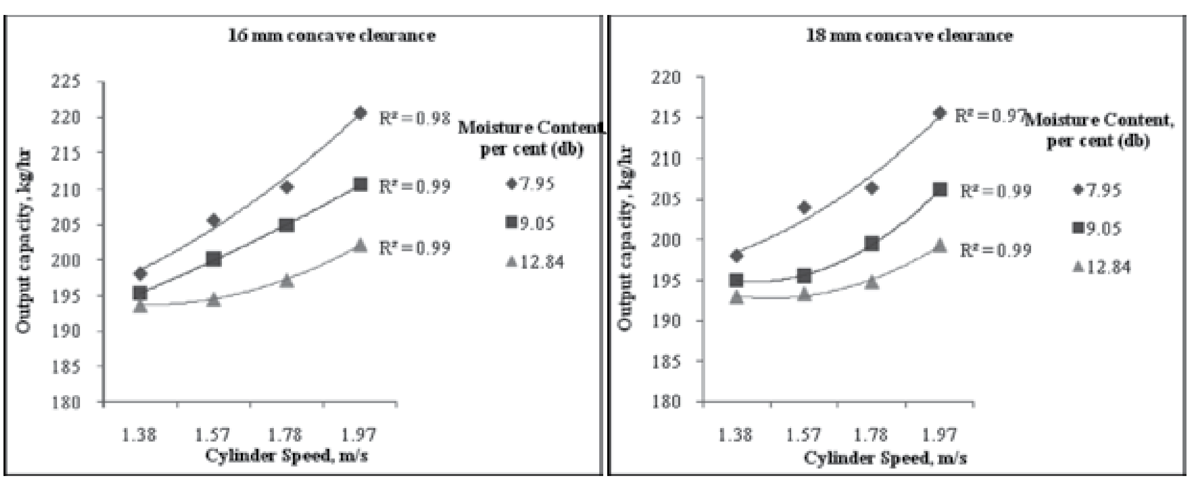

Fig. 5: Effect of cylinder speed and moisture content on output capacity at different concave clearances

efficiency, cleaning efficiency, percentage seed loss and output capacity increased with increase in cylinder speed whereas mechanical damage decreased for all moisture content level. Hence to achieve higher decortication efficiency, cleaning efficiency and output capacity with corresponding low percentage seed loss and mechanical damage, moisture content of 9.05 per cent (d.b.), 1.97 m/s cylinder speed and 16 mm concave clearance were found ideal.

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Rain water Harvesting and Drip Irrigation Integration in Banana: Experience through Farmer's Participatory Action Research in Assam

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ABSTRACT

Experiment to integrate rainwater harvesting with drip irrigation to increase productivity of Banana was conducted at Assam Agricultural University, Jorhat, Assam during 2009-10. A pond was designed, dug and lined with 200 micron thick LDPE film to cut off seepage losses. The Maximum of 0.50 ha-cm and minimum of 0.23 ha-cm of water was stored in the pond during the month of August and December respectively. The water thus harvested was utilized to irrigate 3400 m^2 of banana (cv. Bor Jahaji, Musa AAA group, Cavendish subgroup) plantation during November to April. Three levels of water application i.e. 1.0 and 0.75 times of pan evaporation (PE) measured by a USDA Class-A pan and no irrigation and three levels of mulching i.e. black plastic mulch, paddy straw mulch and no mulch was tested in a 3 x 3 factorial experiment in randomized block design (RBD). The analysis of data revealed that drip irrigation at 0.75 times PE produced the highest pseudostem height (275.28 cm), pseudostem girth (67.47 cm), total number of leaves (36.53) , bunch weight (26.26 kg), hands/bunch (9.70), finger/hand (19.89) and yield (81.05 t/ha). Paddy straw mulch appeared superior to black plastic mulch and it recorded better pseudostem height (277.94 cm), number of leaves (36.74), pseudostem girth (68.41 cm), hands/bunch (9.75) and the total yield (80.07 t/ha). The technology was tested in farmers' field in 3 locations through participatory action research during 2011-12. Increase in yield of up to 25% and BCR up to 4.17 was achieved in the farmers participatory action research.

Key words: *Rain water harvesting, Drip irrigation, Paddy straw mulching, Banana*

INTRODUCTION

Indian subcontinent on an average receives high monsoon rainfall for about four months. However remaining months remain mostly dry. Therefore, rain water harvesting is a viable option in India. The concept of rainwater harvesting is not new in India. The country has a long tradition of water harvesting. But unfortunately many of the traditional water harvesting system have either fallen into disuse due to variety of physical, social, economic and cultural and political factors which have caused their deterioration, decline of institutions which has nurtured them (Agarwal and Narain, 1997) or have lost their relevance in the modern day context due to their inability to meet the desires of the community. The decline in water harvesting tradition has been well researched and documented but increase in the community acceptability is much less understood and appreciated (Kumar et al, 2006). Only water harvesting may not be adequate to sustain interest of community in modern day context. There is a need for integration of water harvesting with appropriate technology for judicious use of the water so harvested to sutain interest of the stakeholders.

Although Assam receives high rainfall in the tune of 1954 mm per annum (Anonymous, 2010) but the distribution is erratic. Most of the rainfall occurs during May-August. The remaining months i.e.

October-April is virtually dry with only 2-3 per cent of the total rainfall interception. Therefore crop suffers from moisture stress that results in reduction in productivity and quality of produce and sometimes both. Use of ground water for irrigation is restricted by high iron content and contamination with arsenic and fluoride. Harvesting of rain-water during *kharif* and using it during *rabi* is a possibility. But harvesting rainwater involves cost and thus water so harvested needs to be utilized efficiently through appropriate technology. Drip irrigation has established itself as a useful technology for efficient water management.

Banana is a major fruit crop of Assam grown in an area of 45,000 ha with production of 6.22 lakh tones and productivity of 13,823 kg/ha (Anon 2011). Climate and soil conditions of Assam is ideal for its commercial cultivation but banana has high evaporative demands and requires liberal supplies of irrigation water for growth and production. The erratic distribution of rainfall leads to significant depletion of soil water during growing season and affects productivity of crop. Although, there is enough potential for integration of rainwater harvesting, drip irrigation and mulch to increase productivity of banana, no concerted effort has so far been made in this direction. Since farmer's are the end user of agricultural technologies, such technologies are best perfected by farmer's themselves. Therefore, an effort was made to integrate rainwater harvesting with drip irrigation to increase productivity of Banana in Assam involving farmer's.

MATERIAL AND METHODS

The experiment on integration of rainwater harvesting and drip irrigation to increase productivity of banana was conducted at experimental farm, Department of Horticulture, Assam Agricultural University, Jorhat (26º47´N latitude, 94º12´E and 86.8 m msl).

Design of water harvesting pond: The meteorological records of Jorhat during 2004-2009 were collected from meteorological observatory at Assam Agricultural University, Jorhat and presented as Fig.1. These data were used for estimation of water requirement and designing of water harvesting pond. The capacity design of the pond was done using the equation (Kumar and Singh, 2010)

$$V = \frac{H}{2}\{(a-2f)(1-2f)+(l-2H-2f)(a-2H-2f)\}$$

$$V = \frac{H}{2}\{(a-2f)(1-2f)+(l-2H-2f)(a-2H-2f)\} \quad ...(1)$$

Where

L= top length of pond, m

H= depth of pond, m

A= top width, m

F= free board, m

The capacity thus designed was matched with water requirement of banana plantation for 3400 m^2 to meet irrigation requirement at 1.00 times pan evaporation (PE) measured by a USDA Class-A pan. A dead storage of 1 m was kept for fish rearing as additional income generation. The dimension of the pond was so designed that it had the dimension of a = 26 m, l = 76 m, f = 0.15 m and H = 3 m with side slope of 2:1 (2 horizontal to 1 vertical). The pond was oriented in north-south direction to reduce wave action. Black low-density polyethylene (LDPE) film of 0.25 mm thickness (as per IS: 2508-1984) was used for lining the pond. A uniform soil cover of 30 cm was provided over the lining film. The experimental site experiences high water table during rainy season. To protect the film from rising water level perforated 1.2 cm LLDPE (linear low density polyethylene) pipes were laid below the lining film for pressure relief. The pond was dug using manual labour. Bottom and sides of the excavated pond was rammed for compaction and consolidation and polished to remove any projections. Weedicide (butachlor, 2.0 kg of a.i./ha) was sprayed on the bottom and sides one day before the laying of the film. The size of the lining film was estimated using the equations:

Size of film, $m^2 = L \times W$ ... (2)

Where,

L= length of the film, m

W=width of the film, m

$$L = b + 2\sqrt{(nh)^2 + h^2} + 2 \quad ...(3)$$

Where,

b= bottom length of the pond, m

n= side slope (n:1)

h= depth of pond, m

$$W = c + 2\sqrt{(nh)^2 + h^2} + 2 \quad ...(4)$$

Where,

c= bottom width of pond, m

The lining film was then laid as per procedure given in research bulletin of Directorate of Water Management (ICAR), Bhubaneswar (Kumar and Singh, 2010). The location of the pond and sectional view are presented in Fig. 2. Observation on yield of the pond and water quality was taken.

Drip irrigation experiment: Banana suckers (cv. *Bor Jahaji,* Musa AAA group, Cavendish subgroup) were planted at 1.8 m x 1.8 m spacing in an area of 3400 m^2 in May, 2010 for the drip irrigation studies. The soil of the experimental site consist of old alluvial soil with sandy loam structure (69.6% sand, 9.4% silt, 21% clay), acidic reaction (pH 4.6), medium organic carbon (0.69%), medium in available nitrogen (282.84 kg /ha), available phosphorus (30.24 kg/ ha) and potash (94.08 kg/ha), maximum water holding capacity (14.2%) and bulk density 1.56 kg/ m^3. To achieve the objective of the study an experiment based on 3x3 factorial arranged in a randomized block design with three replications was laid out. Three levels of irrigation (viz. 1.0, , 0.75 times of PE and non irrigated) and three levels of mulch (viz. black plastic mulch of 50 micron thickness, paddy straw mulch and no mulch) were tested. Pan evaporation *(*PE) measured by a USDA Class-A pan was collected from meteorological observatory of Assam Agricultural University, Jorhat. Different fractions of PE i.e. 1.0 and 0.75 times PE values were worked out. The fractions (mm) were then converted to volumetric unit (ml) by multiplying the row spacing (m) and plant spacing (m) of the plant. To deliver the estimated volume of water one 4 LPH (liters per hour) dripper was fitted on 1.2 cm diameter lateral. Each lateral was provided with a lateral valve to regulate the flow as per different treatment. No irrigation was given when rainfall exceeded evaporation. The emission uniformity of the system was checked periodically to maintain it above 85%. To evaluate the relative effectiveness of each treatment, data on growth (pseudo- stem height, pseudo- stem girth and number of functional leaves) and yield was recorded.

The economic feasibility was determined through benefit-cost analysis. The annualized cost of drip irrigation included depreciation, prevailing bank interest rate, repair and maintenance of the system. The interest rate and repair and maintenance cost of the system were 12 and two percent per annum of the fixed cost, respectively (Rao, 4). The useful life of drip system was considered to be seven years. The cost of banana cultivation included expenses incurred in fertilizer, plastic mulch, and crop protection measures and harvesting. Benefit-cost ratio, total cost of production and net return from growing banana in 1 ha land were then estimated.

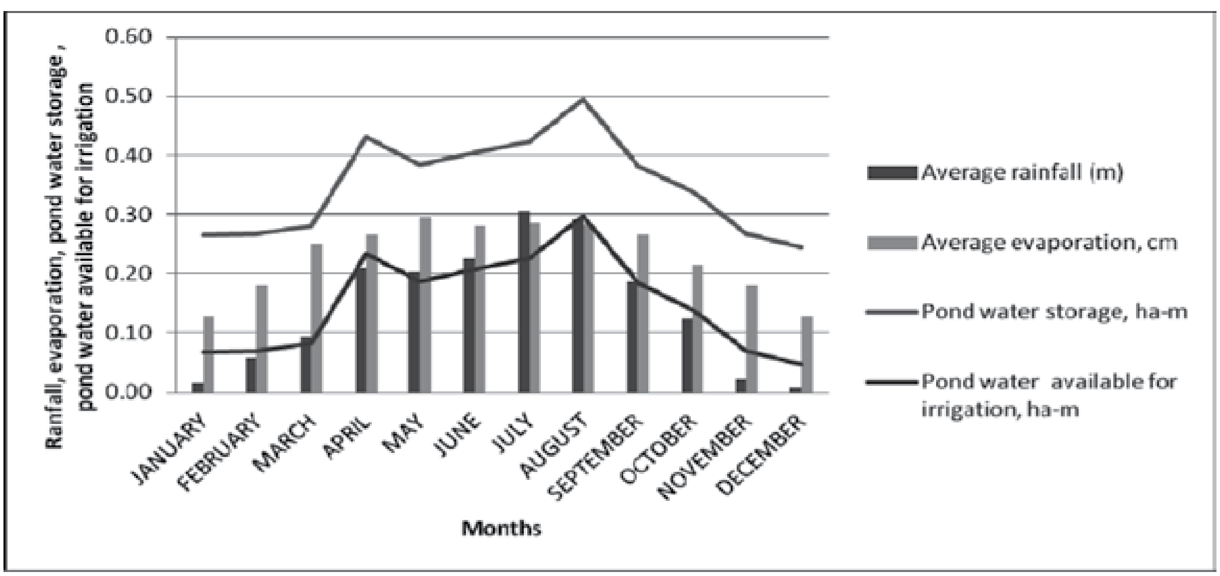

Fig. 1: Average rainfall and evaporation of study area, water stored in pond and water available for irrigation

The best results from the research were tested in farmer's field in three districts of Assam, namely, Jorhat, Sonitpur and Bongaigaon in association with KVKs of the respective districts during 2011-12. Ponds were dug for rain water harvesting at farmer's field during March 2011. The capacity of the structures corresponded to water requirement of best treatment and dead storage of 0.5 m taking into account the evaporation loss of respective location. The side slope was 2:1 and other dimensions were worked out using equations 1, 2, 3 and 4. Banana (cv. *Bor Jahaji,* Musa AAA group, Cavendish subgroup) was planted in farmer's field in 1 ha area in each location in May 2011. Drip irrigation system was installed for the crop in November 2011. Drip irrigation system was operated during November, 2011 to March, 2012 using pond water. Observation on yield and water used was recorded and benefit-cost ratio was worked out.

RESULTS AND DISCUSSION

The water stored was measured using staff gauge installed in the pond. Maximum and minimum water stored in pond was 0.50 ha-cm and 0.23 ha-cm respectively in the month of August and December respectively. Water stored in the pond and water available for irrigation peaked during the month of August. It was because rainfall was also highest during July-August. The water stored in the pond started receding from August till April in the following year because of evaporation loss. The water stored increased slightly in January because of winter rainfall. Iron content of pond water and ground water from tubewell was measured and iron content of ground water was found to be 1.6 mg/l which posed severe clogging hazard for drip irrigation (Dasberg and Or, 1999). The iron content in pond water was found to be 0.5 mg/l which posed only

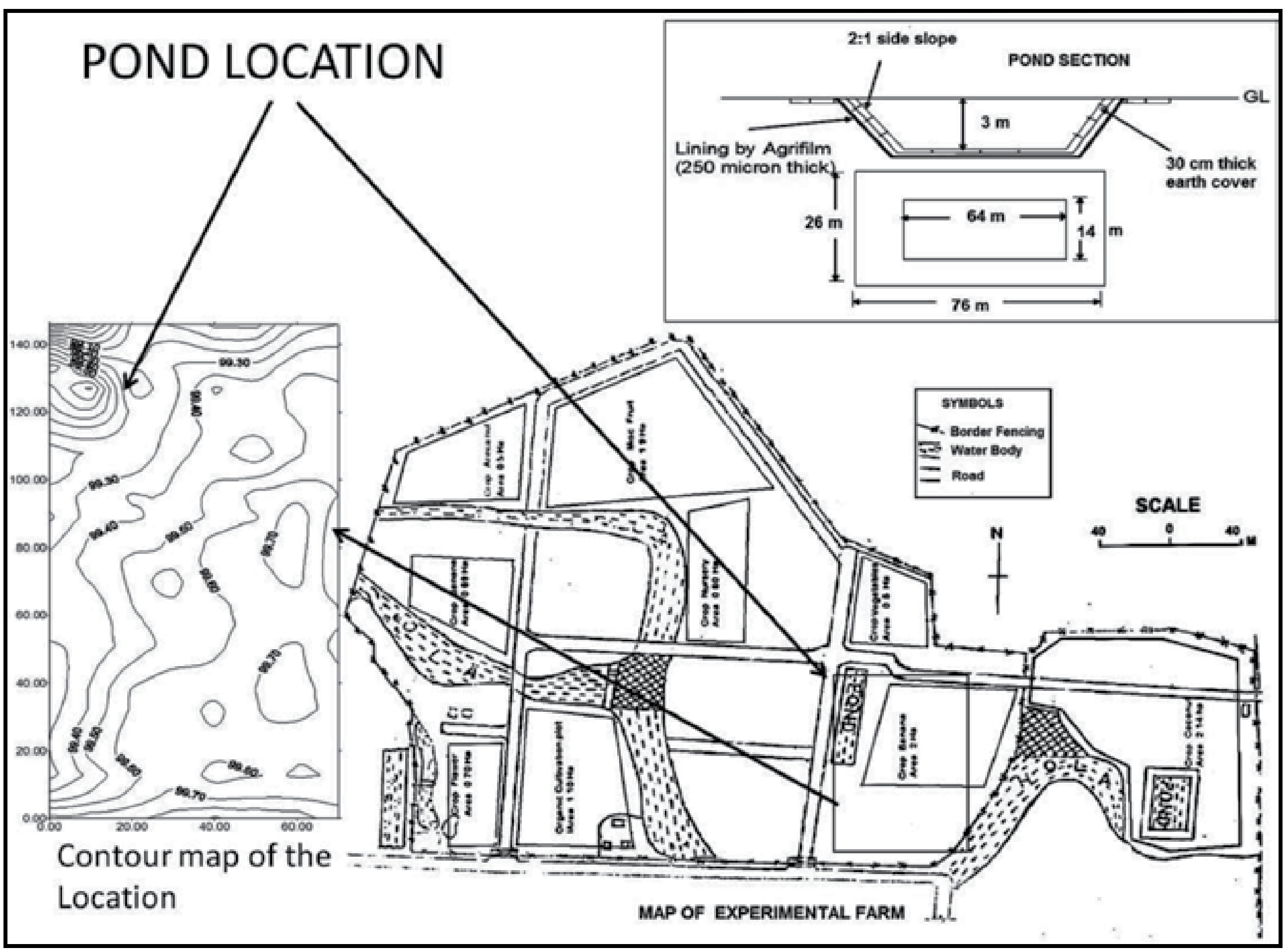

Fig. 2: Location and section of pond

slight clogging hazard. Pond water therefore offered a better alternative to ground water for drip irrigation in the study area.

Analysis of data (Table 1) revealed that highest yield was recorded for the treatment where plants were irrigated using drip irrigation with 0.75 times PE and was mulched with paddy straw. Highest water use efficiency (WUE) was also recorded for this treatment. Study of the factors revealed that both irrigation levels and mulching influenced growth characters and yield of banana. Irrigation with 0.75 times PE produced the best growth character (pseudo- stem height (275.28 cm) , pseudo- stem girth (67.47cm) and number of functional leaves (5.73), best yield character (bunch weight (23.11 kg), hands/bunch (8.72), fingers/hand (19.51) and fruit yield (72.00 t/ha) while the control (no irrigation and no mulch) plants produced the lowest values in respect of the these parameters (Table 2). The increased growth of banana due to drip irrigation might be attributed to the fact that soil moisture in the active root zone was kept near to field capacity through the growing period, resulting in low soil suction, which facilitated better water and nutrient

Table 1: Banana yield as influenced by irrigation level and mulches

	Treatments	Yield (t/ha)	CU (cm)	WUE (t/ha-cm)
1.00 times PE	T1	73.37	190.32	0.39
0.75 times PE	T2	72.45	188.54	0.38
Black plastic mulch (BPM)	T3	51.10	188.99	0.27
Paddy straw mulch	T4	46.32	198.78	0.23
1.00 times PE + BPM	T5	74.35	199.65	0.37
0.75 times PE + BPM	T6	75.36	189.56	0.40
1.00 times PE + Paddy straw	T7	79.54	199.96	0.40
0.75 times PE + Paddy straw	T8	80.56	192.31	0.42
Control	T9	29.36	190.43	0.15
	$CD_{0.05}$	5.81	2.25	0.02

Table 2: Growth and yield of banana as influenced by drip irrigation and mulching

Treatments	Growth			Yield			
	Pseudo-stem Height (cm)	Pseudo- stem Girth (cm)	No. of Functional leaves	Hands/ Bunch	Finger/ Hand	Bunch Weight (kg)	Yield (t/ha)
A. Drip Irrigation :							
1.00 times PE	265.89	66.11	5.13	8.42	19.21	22.46	70.33
0.75 times PE	275.28	67.47	5.73	8.72	19.51	23.11	72.00
Non irrigated	245.06	64.00	4.75	7.35	18.05	19.76	61.00
$CD_{0.05}$	3.76	1.07	0.18	0.08	0.06	0.08	0.07
B. Mulch:							
Paddy straw	277.94	68.41	5.66	9.81	19.62	24.15	73.56
Black plastic mulch	272.39	67.50	5.55	8.13	19.25	23.00	71.51
No mulch	235.89	61.67	4.40	7.19	17.81	18.23	56.25
$CD_{0.05}$	3.76	1.07	0.18	0.08	0.06	0.09	0.07
A × B	NS	NS	NS	NS	NS	0.17	0.11

uptake by the plants. In mulching paddy straw mulch recorded significantly better pseudostem height (277.94 cm) and number of functional leaves (5.66). In case of yield characters also, paddy straw mulch produced significantly highest hands/bunch (9.81) and the total yield (73.56 t/ha). The superiority of paddy straw mulch in terms of growth and yield characters of banana, could be ascribed to increased availability of plants nutrients, specially potassium and soil organic carbon in addition to the higher soil moisture level. Economic analysis of banana cultivation from 1 ha area using drip irrigation from pond water was done (Table 3). The net seasonal income was found to be highest (₹ 3,21,843/ha) in drip irrigation with 0.75 times PE with paddy straw mulch followed by treatment '1.00 times PE with paddy straw mulch' (₹3,16,743/ha). Highest benefit–cost ratio of 3.98 was obtained for drip irrigation with 0.75 times PE with paddy straw mulch. Similar results were reported for drip irrigated banana crop in Assam (Kashyap *et al.*, 2004). Earlier researchers also reported similar results for integration of rain water harvesting and drip irrigation for Assam lemon (Barua, 2013)

T1=1.00 times PE, T2=0.75 times PE, T3=black plastic mulch (BPM), T4=paddy straw mulch, T5=1.00 times PE + BPM , T6=0.75 times PE + BPM, T7=1.00 times PE + paddy straw, T8=0.75 times PE + Paddy straw, T9= control (non irrigated + non mulched)

Results from farmer's participatory action research showed higher yield, WUE and B:C ratio for drip irrigated and mulched plants (Fig. 3). Among the locations Jorhat district recorded the highest increase in yield (25%), highest WUE (0.43 t/ha-cm) and highest B:C ratio of 4.17.

Table 3: Comparative economics of drip irrigation and mulching in banana

S. No	Item	T1	T2	T3	T4	T5	T6	T7	T8	T9
1	Fixed cost ₹	90000	90000	0	0	90000	90000	90000	90000	0
	A) Life (yrs)	7	7	0	0	7	7	7	7	0
	B) Depreciation ₹	12857	12857	0	0	12857	12857	12857	12857	0
	C) Interest (12%) ₹	10800	10800	0	0	10800	10800	10800	10800	0
	D) Repair and Maintenance (7%) ₹	6300	6300	0	0	6300	6300	6300	6300	0
	E) Pond (annualized) ₹	17000	17000	17000	17000	17000	17000	17000	17000	17000
	Total (B+C+D+E) ₹	46957	46957	17000	17000	46957	46957	46957	46957	17000
2	Cost of Cultivation									
	a) Cost of Mulching (annualized) ₹	0	0	25000	5000	25000	25000	5000	5000	0
	b) Fertilzer ₹	27000	27000	27000	27000	27000	27000	27000	27000	27000
	c) other cost ₹	2000	2000	2000	2000	2000	2000	2000	2000	2000
	Total a+b+c	29000	29000	54000	34000	54000	54000	34000	34000	29000
3	Seasonal Total Cost (1+2)	75957	75957	71000	51000	100957	100957	80957	80957	46000
4	Yield (t/ha)	73.37	72.45	51.10	46.32	74.35	75.36	79.54	80.56	29.36
5	Selling Price (₹/t)	5000	5000	5000	5000	5000	5000	5000	5000	5000
6	Income from produce (₹/ha) (4*5)	366850	362250	255500	231600	371750	376800	397700	402800	146800
7	Net seasonal income (6-3) ₹	290893	286293	184500	180600	270793	275843	316743	321843	100800
8	Benefit-cost ratio	3.83	3.77	2.60	3.54	2.68	2.73	3.91	3.98	2.19

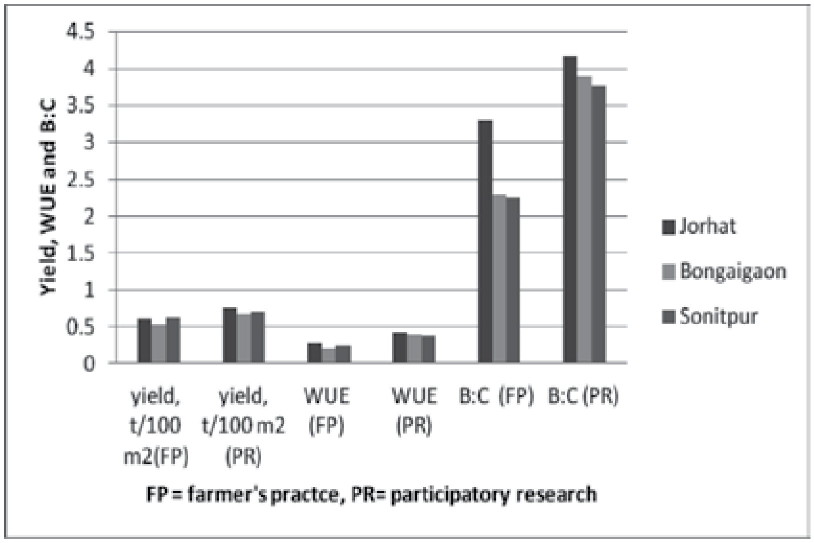

Fig. 3: Yield, WUE and B : C ratio of farmer's participatory action research

CONCLUSION

Water harvesting in pond and subsequent use through drip irrigation increased productivity of banana in Assam. Water application of 0.75 times PE and mulching with paddy straw increased yield by 174% compared to non irrigated and non mulched crop. Net seasonal income was ₹ 3,21,843/ha as compared to ₹ 100800 /ha and benefit –cost ratio was 3.98 as compared to 2.19 for non irrigated and non mulched crop. Benefit –cost ratio was 3.76 to 4.17 in farmer's participatory action research. From the above study, water harvesting in pond during *kharif* and use it through drip irrigation in *rabi* for banana cultivation was found to be economically viable for Assam.

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Moisture Sorption Properties of Castor Seeds

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ABSTRACT

Equilibrium moisture contents were determined for Gray Small Size (GSS) and White Big Size (WBS) castor seeds at 30, 40, 50, 60 and 70°C and water activities in the range of 0.07 to 0.98. Four sorption models namely modified Henderson, Halsey, Oswin, and Guggenheim Anderson de Boer (GAB) were applied for analyzing the experimental data. The curve-fitting of the sorption data was evaluated using non-linear regression analysis and compared using the standard error of estimate, mean relative percent deviation, fraction explained variation and residual plots. The sorption capacity of the seeds decreased with increase in temperature at constant water activity and increased with increase in water activity at constant temperature. The isotherms curves were sigmoidal in shape and of type II behavior according to BET classification. The modified Oswin model was the most suitable for describing the relationships between equilibrium moisture content, relative humidity and temperature at desorption while at adsorption. The Modified GAB predicted a type I sorption curve for a type II BET classification obtained experimentally. Sorption hysteresis occurred with higher values as the temperature increased. These are useful information for this less researched drought resistant oil crop whose processing is still at traditional manual level.

***Key words**: Sorption isotherm, Sorption hysteresis, Gray small size, White big size.*

INTRODUCTION

Castor (*Ricinus communis* L.) is an oil seed crop that is abundant in the North eastern states especially southern part of Borno state and South-Eastern states of Nigeria. The seeds are ovoid, compressed dorsally, tick-like shining, pale grey (hereafter referred to as Grey Small Size, GSS) or yellowish white and big size (hereafter known as White Big Size, WBS). The seeds of WBS and GSS respectively contain 21-24 and 20 - 23% protein, 44-48 and 43-49% fat, 2-5 and 3-10% crude fibre, 3-8 and 3-11% ash and moisture content of 5-8 and 4-8% (Annongu and Joseph, 2008; Akande *et al.*. 2012) which are also in agreement with the results of preliminary studies carried out under this study. Castor oil is inedible used as raw material in several industrial applications; biofuels (Gely and Santalla, 2009), vanishes and paints.

The necessities of the knowledge of the relationship between the equilibrium moisture content (EMC) and the equilibrium relative humidity (ERH) or water activity in drying have been discussed in a number of research reports (Sun and Woods, 1994; Ojediran and Raji, 2010, 2011; Raji and Ojediran, 2011) while the importance of moisture sorption isotherm models as essential components in drying theory were also highlighted (Myhara *et al.,* 1998; Aviara *et al.,* 2004; Medeiros *et al*., 2006, Raji and Ojediran, 2011). Moisture sorption isotherm curves form the basis of understanding the sorption characteristics of food and these curves are always unique to each food under specified conditions.

Several studies have been reported on food materials but published studies on the equilibrium moisture-water activity relations of castor, which determine the behaviour of this oilseed during post-harvest handling, (mainly storage and drying processes) are limited. Sorption properties over a wide temperature range are essential for modeling dehydration or rehydration processes and storage stability of dehydrated foods (Saravacos *et al.,* 1986). As a result, there is a need to evaluate the equilibrium moisture properties of castor seeds and to determine the effect of temperature on the sorption isotherms. The objectives of this work were to investigate the equilibrium moisture contents of castor seeds in the temperature range that are usually applied in post-harvest processes, evaluate the moisture sorption isotherm models that could predict the equilibrium values at the temperatures and estimate the effect of temperature on moisture sorption hysteresis in castor seeds.

MATERIALS AND METHODS

Bulk quantities of castor seeds (*Ricinus communis* L.) namely: Grey Small Size variety (GSS) and White Big Size variety (WBS) were obtained from farms in Maiduguri, Borno State and Ihiala, Anambra State, Nigeria, respectively, and used in this study. The seeds were prepared using the processes presented in Raji and Ojediran (2011). The Moisture Content (MC) of the seeds for desorption experiments were raised to 17 and 18% (db) within the range obtainable at harvest by addition of calculated amount of water and controlled oven drying was done to reduce the moisture content to 3.23 and 3.95% (db) which were below the market stable storage MC for adsorption experiments from initial MC of 4.80 and 5.24% (db) for GSS and WBS castor varieties respectively.

Equilibrium moisture content of castor seeds was experimentally determined using the static gravimetric method with saturated saline solutions of known relative humidity varying between seven and 98% at 30, 40, 50, 60 and 70°C. Excess salt was maintained in each solution. The desiccators containing the salt solutions and samples of castor were marked and placed inside temperature-controlled Gallenkamp DV 400 ovens (Weiss Gallenkamp, UK) which were set at the desired temperature. The samples were weighed daily using a Mettler PC2200 DeltaRange analytical balance (Mettler-Toledo Inc., USA) with an accuracy of 0.001g. The dry matter content of samples was obtained by oven drying at 130^{o}C for 18h (ASAE, 1983). The sorption experimental data of the seeds were fitted to four moisture sorption isotherm models (Table 1) using non-linear regression procedure as reported by Raji and Ojediran (2011).

The goodness-of-fit of each model was evaluated using the standard error of estimate (SE); mean relative percentage deviation (P), fraction explained variation (FEV) and nature of the residual plots Low values of *P* and SE, and higher FEV and high

Table 1: Moisture Sorption Isotherm models used

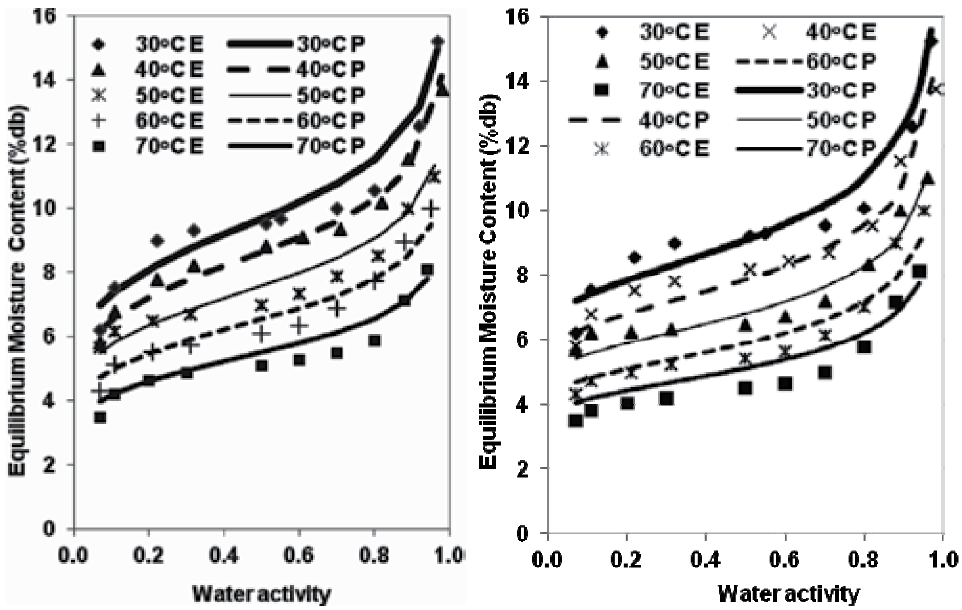
Model	Equation	Sources
Modified Henderson	$M_e \approx \left[\frac{-\ln(1-a_w)}{A(T+B)}\right]^{1/C}$	Thompson, 1972; Gely and Santalla, 2009
Modified Halsey	$M_e \approx \left[\frac{-In\ a_w}{\exp(A+BT)}\right]^{-1/C}$	Iglesias and Chirife, 1976; Menkov *et al.*, 2004
Modified Oswin	$M_e \approx (A+BT)\left[\frac{a_w}{1-a_w}\right]^{1/C}$	Sanjeev and Singh, 2006; Raji and Ojediran, 2011
Modified GAB	$M_e \approx \frac{AB\left(C/T\right)a_w}{(1-Ba_w)(1-Ba_w+\left(C/T\right)Ba_w)}$	Van den Berg, 1984; Timoumi *et al.,* 2004) as modified by Jayas and Mazza (1993).

where M_e is Equilibrium Moisture Content, a_w is the water activity, T is the temperature while A, B, and C are constants.

degree of randomness in the residuals indicate a superior model. Hysteresis loop for each of the varieties resulting from adsorption and desorption were plotted and the variation with temperature were determined.

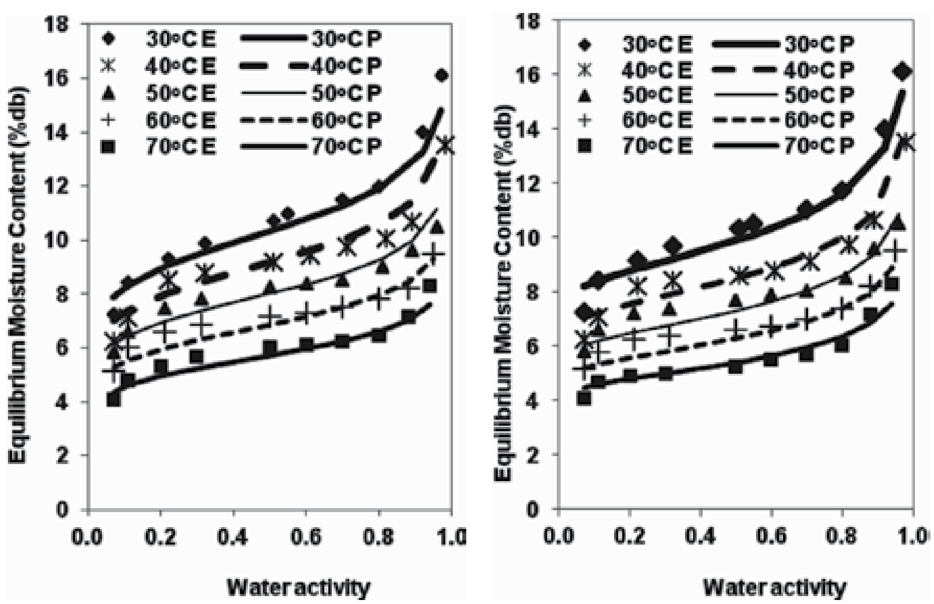
RESULTS AND DISCUSSION

Moisture Sorption Isotherms: The adsorption and desorption isotherms of GSS castor at 30 - 70°C over the a_w range of 0.07-0.98 as data points having the predicted curves are presented in Figs. 1 and 2. The equilibrium moisture content increased with increase in water activity at constant temperature and the curves had the sigmoidal-shaped profile exhibiting the typed II behavior according to the BET classification (Andrae *et al.*, 2011). Similar trend was



(a) Modified Oswin (Desorption) (b) Halsey model (Adsorption)

Fig. 1: Moisture sorption isotherms of GSS castor seed with (E = Experiment, P = Predicted)



(a) Modified Oswin (Desorption) (b) Halsey model (Adsorption)

Fig. 2: Moisture sorption isotherms of WBS castor seed (E= Experiment, P = Predicted).

observed in WBS variety. These curves were typical of legume and oil seeds as reported by Mazza and Jayas (1991), Menkov (2000), Vazquez *et al.* (2003), Tarigan *et al.* (2006) and Raji and Ojediran (2011).

A decrease in equilibrium moisture content with temperature was observed at constant water activity. This can be explained by the higher active state of water molecules at higher temperature thus decreasing attractive forces between them (Yan *et al.,* 2008). Similar trends for many seeds have been reported (Mazza and Jayas, 1991; Suthar and Das, 1997; Walters and Hill, 1998; Menkov, 2000; Tarigan *et al.*, 2006; Akanbi *et al.*, 2006; Yan *et al.*, 2008; Raji and Ojediran, 2011). The EMC models indices and constants as well as the statistical analysis outputs are as presented in Tables 2 and 3. Modified Oswin model fitted best for desorption while the modified Halsey fitted best and predicted temperature effect better in adsorption for both seeds. The modified Henderson model too could be acceptable for predicting the adsorption EMC but P was high. As was the case with GSS seed, this is also a proof of the predictive ability of the modified Oswin and Halsey models for the EMCs of WBS castor seed. The Modified GAB did not predict the temperature effect well (Fig. 3) as it predicted a type I sorption curve under BET classification for a type II classification obtained experimentally.

Aviara *et al.* (2006) stated that the standard error of estimate alone is not adequate and that the nature of the residual plots should be considered in determining the goodness of fit of a model. As a result, the trend obtained in the residual plots of the distribution of the data is presented in Tables 2 and 3

Table 2: Estimated parameters and comparison criteria for GSS castor seeds

Parameter and Criteria	Equilibrium moisture content models							
	Modified Halsey		Modified Henderson		Modified Oswin		Modified GAB	
	Ads.	Des.	Ads.	Des.	Ads.	Des.	Ads.	Des.
A	37.86	44.701	1.33×10^{-5}	415.271	41.149	93.621	-11.129	17.851
B	-0.084	-0.080	-316.687	8.000×10^{8}	-0.106	-0.231	-6.560	0.346
C	5.799	6.612	4.530	4.761	7.383	8.155	315.674	20378.81
SE	0.507	2.056	0.623	3.879	0.548	1.614	1.569	3.885
P	6.444	10.364	7.661	99.969	6.121	8.231	18.829	17.687
FEV	0.996	0.990	0.985	0.965	0.995	0.994	0.961	0.965
Residual plot	Random		Patterned		Random		Patterned	

A, B and C are constants; SE the standard error of estimate, P the mean relative percent deviation and FEV the fraction explained variation.

Table 3: Estimated parameters and comparison for WBS castor seeds

Parameter and Criteria	Equilibrium moisture content models							
	Modified Halsey		Modified Henderson		Modified Oswin		Modified GAB	
	Ads.	Des.	Ads.	Des.	Ads.	Des.	Ads.	Des.
A	48.741	50.009	1.74×10^{-7}	2.10×10^{-9}	45.705	45.167	-12.603	-13.529
B	-0.108	-0.108	-319.17	-323.000	-0.117	-0.115	-8.015	-7.67
C	7.147	7.591	6.669	7.315	9.159	9.636	310.832	309.145
SE	0.389	0.469	0.424	1.013	0.439	0.418	1.281	1.116
P	4.25	4.883	15.422	21.487	4.627	4.164	13.233	10.865
FEV	0.998	0.997	0.994	0.983	0.997	0.998	0.977	0.984
Residual plot	Random		Patterned		Random		Patterned	

A, B and C are constants; SE, the Standard Error of Estimate; P, the mean relative percent deviation and FEV, the Fraction Explained Variation.

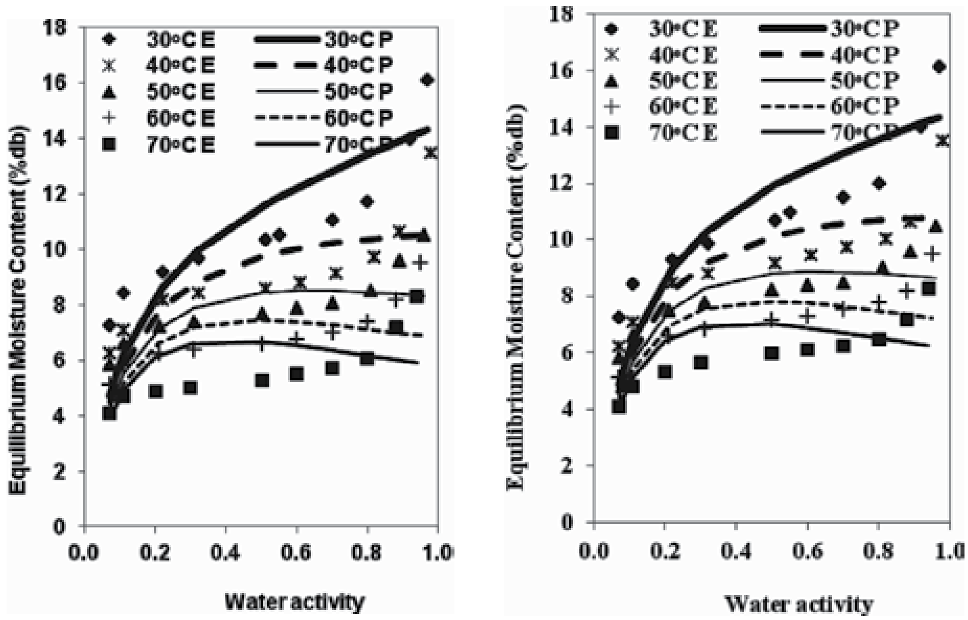


Fig. 3: Modified GAB model prediction for WBS castor seed (a) Desorption (b) Adsorption (E = Experiment, P = Predicted).

and Fig. 4. Modified Oswin gave random plots (Fig. 4a) which are indications of good fit for adsorption and desorption while the Modified GAB gave a patterned distribution (Fig. 4b) which does not describe and predict the temperature dependence of the EMC data adequately.

Moisture Sorption Hysteresis: The Moisture Sorption Hysteresis (MSH) loops are presented in Fig. 5 with the adsorption isotherms at different temperatures lying below their desorption counterparts. Both enclosed a hysteresis loop of the third type according to Kapsalis (1987) classification. The reasons for the hysteresis were discussed by

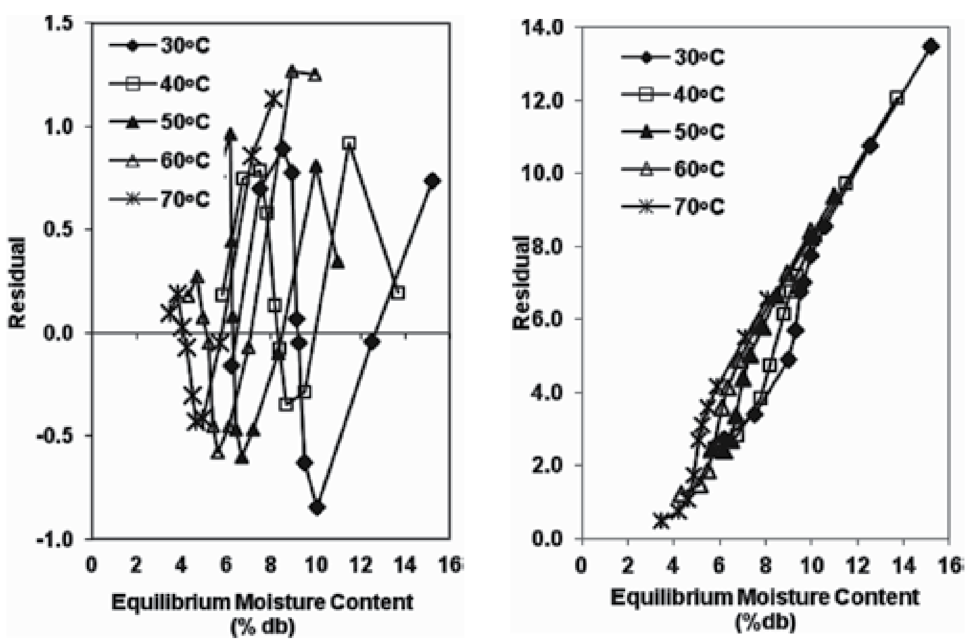


Fig. 4: Residuals of (a) Modified Oswin model (GSS Adsorption) (b) Modified GAB model (GSS Desorption)

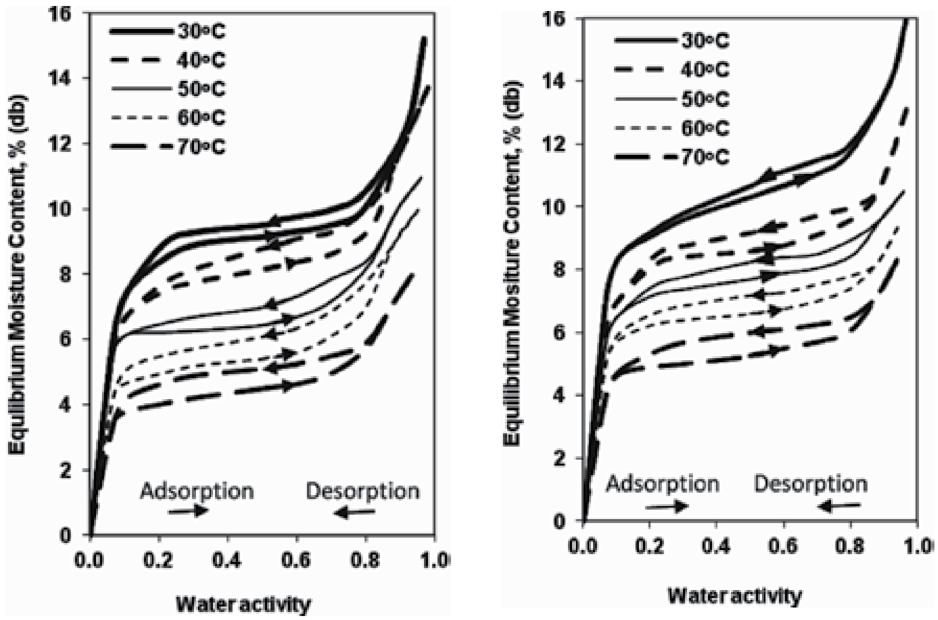


Fig. 5: Moisture sorption hysteresis (a) GSS castor (b) WBS castor

Yan *et al*. (2008) and Raji and Ojediran (2011). This study presents the hysteresis loop in a continuous curve using arrows to show the adsorption and desorption. The data points are as indicated in Figs. 1 and 2.

It can be seen that the hysteresis loop commenced in both varieties, at a_w below 0.2 for all the temperatures while the terminations were all above a_w of 0.8. The higher the temperature, the longer the termination point in the hysteresis curves. This pattern shows that the hysteresis loop for millet reported by Raji and Ojediran (2011) are shorter than for castor an indication of the crop characteristics i.e. millet is harder in nature than castor.

CONCLUSIONS

The moisture sorption isotherms of GSS and WBS castor seeds at temperatures 30 - 70°C have been established. The desorption and adsorption isotherms were sigmoidal in shape with a marked temperature effect. Modified Oswin is the best model to predict desorption equilibrium moisture content for castor seeds and modified Halsey equation best at adsorption. Occurrence of moisture sorption hysteresis in castor was of type three with span increasing with increasing temperature due to the hard nature of the seeds. These are useful in handling the drying and processing operations of this highly used but less researched drought resistant oil crop whose processing is still at the traditional manual level. Further investigation into the number of repeated adsorption and desorption required for closure and disappearance of the hysteresis loop with temperature need to be carried out to obtain the information for the seeds.

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Economic Impact of Custom Hiring Services of Machinery on Farm Economy in Punjab

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ABSTRACT

The study revealed that hiring-in farm machinery services rather than owning the same led to substantial economic benefit to farmers. The farmers owning farm machinery had invested almost two and half times more on this account when compared to the farmers who took the benefits of custom hire services of farm machinery. While, custom hiring of farm machinery resulted into 26% higher operational machine costs; huge saving of investment resulted into comparatively lower fixed costs of crop cultivation on machinery account (depreciation and interest) to the tune of about 63%. Overall, per hectare cost of crop cultivation on farms depending upon custom hire services was about 12 per cent lower than that on the machinery owning farms. Though the returns over variable cost were higher on the machinery owning farms; higher fixed costs outpaced such gains of lower operational costs on these farms and resulted into relatively significant low net returns viz. only Rs. 1038/ha in comparison to Rs. 10,134/ha on the farms depending on custom hire services of farm machinery. Thus, the custom hiring of farm machinery provides a viable option to the farmers especially smaller ones through reduction in total cost of cultivation and increase in profitability. For benefit of the farming community especially smaller ones, the study suggests for strengthening and extension of the custom hiring services of farm machinery through establishing/promoting the Agro Machinery Service Centers throughout the state.

Key words: *Custom hiring, Farm machinery, Farm economy, Agro Service Centre, Owning farm machinery*

INTRODUCTION

Punjab agriculture which has undergone a remarkable change after independence is now the most mechanized in India. The number of all types of farm machinery in state grew exponentially overtime and this large scale farm mechanization along with the use of other complementary inputs has played a significant role in rapid transformation of agriculture in state. However, the green revolution coupled with increasing fragmentation of land has also brought its own share of problems for the agricultural sector. The state is witnessing the negative impacts of intensive farming, wherein the significant increase in fixed costs have endangered the economic viability of farming, especially in the case of small and marginal farmers. While there was a decline in the variable costs of production of rice and wheat in the state during 1980s and 1990s, the fixed costs showed a gradual increase during this period (Sidhu *et al.,* 2005). The over capitalization of the agriculture in the state, particularly on the front of farm mechanization can be ascertained from the fact that more than 30 per cent of the small farmers operating less than 2 ha owned tractors (Singh *et al*., 2007). To become viable a tractor needs to run for 1,000 hours per annum, however in Punjab the average use of tractor is just 250 hours per annum. Overtime, tractor has become a symbol of prestige and honor and the farmers ironically have even been selling land to buy the machines (Tiwana *et* *al.*, 2007).

More than 60% of the operational holdings in state are of the size less than 4 ha and resources at their command do not make it feasible to go for heavy mechanization due to high investments involved. Single farm ownership and use of heavy and costly machinery on these farms is not economically viable. An alternative to overcome this constraint and at the same time to get the advantages of mechanization is to custom hire the needed machinery and implements. Custom hiring is a popular method of gaining short term control over the various farm operations particularly during the peak season such as preparatory tillage, sowing, harvesting, etc. Custom hiring has several benefits, over other methods of acquiring machine services such as the reduced responsibility of owning and operating the machine, no long term capital commitment, easier planning of a farm budget and providing the farmers with the leverage of time for accomplishing other tasks (Beaton *et al.*, 2003). Custom hiring is particularly beneficial in wake of specialized machines, which are expensive to purchase and it also saves the liquidation of machine just in case the cultural practice changed. The services for custom hiring can be obtained from the large farmers, other private and cooperative agencies. The present study assesses the impact of the custom hiring services of farm machinery and implements on farm economy.

METHODOLOGY

In order to promote the custom hiring services of farm machinery, Government of Punjab has taken the initiative to equip the Primary Agricultural Cooperative Societies (PACS) with the commonly used machines and implements for this purpose. At present the state has 3498 PACS, out of which, about 1206 have opened up the Agro Machinery Services Centers (AMSC). To know the farm level economic impact of the custom hiring services of the farm machinery, four AMSC; two each from Ludhiana and Moga district were selected randomly. Lists of beneficiary farmers getting the custom hiring services of the farm machinery especially the tractors were obtained from each of the selected four AMSC. Most of the custom hiring services were taken by the small and medium sized farmers, while a few large farmers also took these services. These farmers were classified into three farm size categories based on their operational land holdings viz. small (< 2 ha), medium (2 to 6 ha) and large (≥ 6 ha). A total of 64 beneficiaries of these services; 16 each from the four selected AMSC in both the districts were selected in proportion to their number in each of the defined farm size category. To make comparison, an equal number of farmers who owned a tractor and obtained little or no custom hire services and representing each size category were selected from the domain of each of the selected PACS. Thus to analyze the farm level economic impact of the custom hire-in services rather than owning the farm machinery, a total of 128 farmers were selected for the purpose of data collection. The income and expenditure of crop cultivation of both the categories viz. beneficiaries of custom hiring services (entirely dependent upon the custom hiring of the farm machinery) and farmers having their own machinery were compared to work out the benefits of the custom hiring services of farm machinery and implement.

RESULTS AND DISCUSSION

Socio economic characteristics of respondents: The socio-economic characteristics have a profound influence on the decision making process in the context of farm planning and economy. The rural households in a typical village community exhibit great heterogeneity and Punjab is no exception. The socio-economic characteristics such as age, family size, and education level of the head of the family are presented in Table 1. Majority of the farm households across both the categories had a family size of 4 to 8 members. Besides, about 17% of machine owning and 14% of custom hiring farm households had a large family size of 8 and above members. Small families (1 to 4 members) accounted for 1.56% of the total farming households across both the categories. With respect to the age of the head of the families, on both of the farm categories, most of the family heads of the farm households were of 40 to 60 years of age. However, almost 72% of the farmers depending on the custom hiring services fell in this age group as compared to about 67% machine owning farmers. With respect to the education status, farmers depending on custom hiring services had a relatively higher education level than machine owning farmers with 42% of them being graduate

Table 1: Socio economic characteristics of the sample farm households, 2011-12

(Number)

Particulars	Machine owning farms	Custom hire-in based farms
Family size (No.)		
1 to 4	1 (1.56)	1 (1.56)
4 to 8	52 (81.25)	54 (84.38)
≥ 8	11 (17.19)	9 (14.06)
Total	64 (100.00)	64 (100.00)
Age profile of the head of the family (Years)		
20-40	14 (21.88)	15 (23.44)
40-60	43 (67.19)	46 (71.88)
≥60	7 (10.94)	3 (4.69)
Total	64 (100.00)	64 (100.00)
Education level of the head of the family		
Illiterate	6 (9.38)	2 (3.13)
Primary	21 (32.81)	15 (23.44)
Secondary	25 (39.06)	20 (31.25)
Graduate & above	12 (18.75)	27 (42.19)
Total	64 (100.00)	64 (100.00)

Note: Figures in parenthesis indicate the percentage to the total

and above as compared to only 18% of the machine owning farmers with same level of education.

Structure of operational holdings: The size of farm determines the scale of investment as well as access to other required inputs. The total operational area per farm on the machine owning farms and custom hire-in based farms household was 3.73 and 2.26 ha, respectively (Table 2). The incidence of tenancy was relatively very high on machine owning farms as 21.98% (0.82 ha/farm) as compared to only 11.50 per cent (0.26 ha/farm) on the custom hire-in based farms. The reason might be that the machine owning farmers owned most of the agricultural machinery, thus it made economic sense for them to increase the farm size by the means of leasing-in land which lead to a wider spread of fixed costs or in other words resulted in decrease of fixed cost per unit area.

Farm investments: Farm investment, besides playing an important role in agricultural production,

Table 2: Structure of operational holding on the sample farms, 2011-12

(ha/farm)

Particulars	Machine owning farms	Custom hire-in based farms
Owned	2.95	2.06
Leased In	0.82	0.26
Leased Out	0.05	0.06
Total Operational Area	3.73	2.26

also determines the level of fixed costs on the farm. The present value of per hectare farm investment made by the sample farmers is presented in Table 3. The extent of high initial investment on farm machinery on machine owning farms can be observed from the average investment of Rs. 1,29,636/ha as compared to only Rs. 36,465/ha on the custom hire-in based farms. Nearly 75% of the total machinery investment on machine owning farms was incurred on tractor and implements alone, while the corresponding expenditure on the custom hire-in based farms was only 3.46% of the total investment. Thus, tractor and tractor drawn implements were the most expensive items on the farms, accounting for a major share in the total farm investments. The investments on electric motor/ submersible pumps on machine owning farms were Rs. 25,884/ha as compared to Rs. 24,365/ha on the custom hire-in based farms. However, the investment on the generators and diesel engines was higher in the case of later who instead of tractors as a power back up source during the power failure relied on the diesel engines and generators.

Cropping pattern: The cropping pattern indicates the extent of area grown of each crop as a percentage of the total cropped area and is determined by the resource availability of the farm. Table 4 depicts the cropping pattern and the cropping intensity of

Table 3: Per hectare investment on the sample farms, 2011-12

(Rs/ha)

Particulars	Machine owning farms	Custom hire-in based farms
	(i) Machines and implements	
Tractor	72259 (55.74)	-
Implements*	25381 (19.58)	1262 (3.46)
Submersible/Electric motor	25884 (19.97)	24365 (66.82)
Generator + Diesel engine	3230 (2.49)	8132 (22.30)
Others (chaff cutter etc.)	2882 (2.22)	2706 (7.42)
Total	129636 (100.00)	36465 (100.00)
	(ii) Buildings	
Cattle shed	5038 (49.49)	9841 (62.34)
Storage/Implement shed	5143 (50.51)	5946 (37.66)
Total	10181 (100.00)	15787 (100.00)

Note: Note: Figures in parentheses indicate the percentage to the respective total investment.
** Includes tractor drawn implements as well as small/hand tools.*

Table 4: Cropping pattern and cropping intensity of the sample farms, 2011-12

(ha/farm)

Crops	Machine owning farms	Custom hire-in based farms
Rice	3.16 (41.25)	1.88 (42.53)
Maize	0.05 (0.65)	0.02 (0.45)
Wheat	3.29 (42.95)	1.91 (43.21)
Potato	0.27 (3.52)	0.10 (2.26)
Fodder	0.81 (10.57)	0.50 (11.31)
Others	0.08 (1.04)	0.01 (0.23)
Gross Cropped Area (GCA)	7.66 (100.00)	4.42 (100.00)
Net Cropped Area	3.73	2.26
Cropping Intensity (per cent)	205.36	195.58

Note: Figures in parentheses indicate the percentage to G.C.A

sample farms. Rice and wheat crop dominated the cropping pattern across the both the categories of the farmers. The combined percentage of area under wheat and rice crops w.r.t. the gross cropped area on machine owning and custom hire-in based farms was 84.20 and 85.74%, respectively. Other major crops grown on the sample farms were maize, potato, fodder and others (sunflower, mentha, mustard and pulses). The intensity of cropping was observed to be relatively higher on the farms with their own machinery as 205.36% as compared to custom hire-in based farms at 195.57%. Besides having relatively higher cropping intensity, the machine owning farms were relatively more diversified.

Cost of cultivation: The structure of the cost of cultivation provided in Table 5 reflects the proportionate share of various inputs/resources in the total cost of cultivation per ha of net sown area. On machine owning farms, the variable and the fixed cost accounted for 33.27 and 66.73% share of the total cost of cultivation, respectively. In the case of custom hire-in based farms the respective share of the variable and fixed costs was 39.35 and 60.65%. The overall variable cost on machine owning farms (Rs. 47,526/ha) was relatively low than custom hire-in based farms (Rs. 49,551/ha). Custom hire-in of the machine services was the major reason for higher per hectare variable costs on custom hire-in based farms. On these farms the machine component of variable costs was found to be higher by about 26%. As custom hire-in based farms were totally depended on hired services of machinery, their machine component of variable cost was much larger at Rs. 13,605/ha. On the other hand, besides using own machines the machine owning farms had also availed custom services particularly on the account of hiring-in of combine harvester, straw reaper and laser levelers. The hired component of the machine cost on the machine owning farms was lower by about 125% (Rs. 7,528/ha) as compared to the custom hire-in based farms. The per hectare expenditures on seeds, fertilizer and manure and plant protection on the machine owning farms were relatively higher, reason being the relative high intensity of cropping. On the other hand, the amount spent on human labour and irrigation was relatively higher on custom hire-in based farms. The reason for this might be the relative higher use of hired

Table 5: Cost of cultivation structure on the sample farms, 2011-12

(Rs./ha net sown area)

Cost components	Machine owning farms	Custom hire-in based farms	Difference (custom hire-in based farms over machine owning farms)	
			Absolute	%age
(A) Variable costs				
Human labor	17280.03 (12.10)	17634.86 (14.14)	354.83	2.05
Seed	4414.91 (3.09)	3879.13 (3.11)	-535.78	-12.14
Fertilizer & manure	7890.60 (5.52)	7266.54 (5.82)	-624.06	-7.91
Plant protection	3125.40 (2.19)	2838.17 (2.28)	-287.23	-9.19
Irrigation	2326.44 (1.63)	2509.43 (2.01)	182.99	7.87
Machine cost (i + ii)	10881.57 (7.71)	13747.07 (11.05)	2865.51	26.33
(i) Owned	4846.87 (3.39)	142.21 (0.11)	-4704.66	-97.07
(ii) Hired	6034.70 (4.14)	13604.86 (10.90)	7527.54	125.44
Interest on variable costs @ 7 per cent for 6 months	1607.16 (1.13)	1675.73 (1.33)	68.47	4.26
Total variable costs (a + b + c + d + e + f + g)	47526.11 (33.27)	49550.83 (39.35)	2024.72	4.26
(B) Fixed costs				
Land rent	68750.00 (48.13)	66450.00 (52.77)	-2300.00	-3.35
Depreciation	12583.53 (8.81)	4702.68 (3.73)	-7880.85	-62.63
Interest @ 10 per cent	13981.70 (9.79)	5225.20 (4.15)	-8756.50	-62.63
Total fixed costs (a + b + c)	95315.23 (66.73)	76377.88 (60.65)	-18937.35	-19.87
Total costs (A + B)	142841.34 (100.00)	125928.71 (100.00)	-16912.63	-11.84

Note: Figures in parentheses indicate the percentage to the total costs

labour and use of diesel engines and generators for irrigation on these farms.

The fixed cost on farms with own machinery (Rs. 95,315/ha) was 19.87% higher than on the custom hire-in based farms (Rs. 76,378/ha). All the components of the fixed costs viz. land rent, depreciation and interest were relatively higher on the machine owning farms. As machine owning operational holdings had relatively higher proportion of leased in area, land rent on these farms was Rs. 68,750/ha as compared to that of Rs. 66,450/ha on the custom hire-in based farms. Due to high initial investment on farm machines and implements, depreciation and interest costs on machine owning farms were higher than custom hire-in based farms by Rs. 7,881/ha and Rs. 8,757/ha, respectively. Due to non-ownership of farm machinery, the total cost of cultivation on custom hire-in based farms was Rs. 1,25,929/ha significantly lower than that on the machine owning farms (Rs. 1,42,841/ha). Thus, custom hire-in based farms had saved 11.84% on account of opting for the custom hiring services of farm machines and implements rather than owning the costly ones.

Economic benefits of the custom hiring services of farm machinery: It is imperative for the farmers to judiciously use the resources at their command to derive maximum possible per hectare economic benefits, thereby raising the living standard of the farm households. By choosing to obtain the services of custom hiring of farm machinery and implements, farmers especially small and marginal ones not only offsets the fixed costs but also gains leverage of time and can plan his farm budget easily. The gross returns estimated on machine owning farms at Rs. 1,43,880/ha were higher by 5.43% in comparison to the custom hire-in based farms at Rs. 1,36,063/ha (Table 6). This difference of gross returns can be attributed to the relative higher cropping intensity on the machine owning farms. Besides, with relatively low variable cost, the returns over variable cost or in other words the returns to fixed farm resources on machine owning farms were observed to be significantly higher by Rs. 9,842/ha. However, it did not reflect the overall reality on sample farms as this advantage of about 10% on the machine owning farms was outpaced by relatively high fixed cost which was nearly 20% higher in comparison to the custom hire-in based farms. As revealed by the results, the farms using the custom hiring services had significant higher net return at Rs. 10,134/ha as compared to those with ownership of machinery at only Rs. 1038/ha. The difference of net returns i.e. Rs. 9,096/ha (higher on custom hire-in based farms) clearly indicated the importance of custom hiring services of farm machinery and implements in reducing the fixed costs of farming leading to a higher net profitability.

Farmers' perception on AMSC: Farmers' responses regarding qualitative and quantitative aspects of custom hire out services of AMSC revealed that majority (55%) of the farmers rued the unavailability of the machinery from the cooperatives at required time (Table 7). During the peak seasons such as land preparation and sowing, these machines were seldom available on time. Other 30% of the farmers reported the bad condition of the implements due to multiple repairs and 10% faced the problem of frequent breakdown of machinery. Though 40% of the farmers being aware of the problem of the driver with AMSC, they expressed displeasure at the inexperience of the operator (driver) which led to poor quality of work. Nearly 60% of the farmers said they lost the independence which they had if they had their own machinery but also commented that hiring in of the machine and implements from the AMSC saved a lot of costs. Non-availability of particularly required machinery was reported by 15% of the farmers. There were only 5% respondents who rued high charges. Thus, most of the farmers were satisfied with the custom hiring charges fixed by the AMSC. However, about 10% of the farmers

Table 6: Returns over variable cost and net returns on the sample farms, 2011-12

(Rs/ha)

Particulars	Machine owning farms	Custom hire-in based farms	Difference (custom hire-in based farms over machine owning farms)	
			Absolute	Percentage
Gross returns	143879.54	136062.68	-7816.81	-5.43
Return over variable costs	96353.39	86511.86	-9841.53	-10.21
Net returns	1038.22	10134.01	9095.79	876.09

were not satisfied with the attitude of the staff due to prevailing favoritism in providing the machinery services. Overall, the farmers were quiet satisfied by the services offered by the PACS through AMSC and called for further strengthening of these centers, thereby helping the farmers, especially small and marginal to realize higher net incomes.

Table 7: Multiple responses to the problems faced by the farmers in custom hiring of farm machines and implements from AMSC

Problems faced by the farmers	Per cent of the farmers
Problem of timely availability of machinery	55
Attitude of management (favoritism)	10
Condition of machinery/implement, if bad	30
Charges , if high	5
Frequent breakdown of machinery/ implement	10
Non-availability of required machinery	15
Inexperienced or poor operators	40
Lack of independence	60
Need for further strengthening of AMSC, if yes	90

CONCLUSIONS

The study revealed that farmers with their own machinery were having significantly higher operational size of holding as well as higher tenancy as compared to their counterparts availing the benefits of farm machinery custom hire out services of recently established Agro Machinery Service Centers. On the account of the owned machinery, per hectare investment on these farms was much higher as compared to the custom hire-in based farms. The examination of cost of cultivation structure of the own machinery farms vis-à-vis custom hire-in based farms revealed that the total per hectare cost on the later group of farms was about 12% less than that of machine owning farms. There was a significant difference between the machine costs of the two farm groups. Though machine owning farms also had hired some machinery such as combines and laser levelers, the custom hire-in based farms were totally dependent on the hired services of the machines leading to a significant difference between the hired components of the machine cost on these farm groups. Problems as reported by farmers regarding non-availability of required farm machinery as well as availability at crucial time can be solved through increasing the number of commonly used machines and implements at AMSC. Looking at the benefits of the custom hiring services of farm machinery in terms of reduction in the fixed costs of farming and increased profitability, these services needs to be further strengthened and extended throughout the state which can ensure economic viability of farms especially marginal and small ones.

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AGRICULTURAL ENGINEERING TODAY

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The manuscript is to be written in English/Hindi using short and simple sentences. It is to be typed in MS Word using Arial 11 pt. font, double-spacing, on one side of A-4 size paper. The first page is to have the title of the paper, followed by the authors(s)' names(s), Abstract (200 words approx.), a few key words and a footnote giving the authors' affiliation, postal address with PIN code, e-mail address and identifying the Corresponding author. The text of the paper may have main and sub-heads. The manuscript may not exceed 12 pages including the Text, Tables and Sketches. **Please ensure that only SI units are used.** The manuscript should end with a set of crisp and clear Conclusions.

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