Effects of moisture content and feed rate on milling characteristics of wild apricot pits (*Prunus armeniaca* L.)

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Abstract: Milling with decortication of wild apricot pits was done in wild apricot pit decorticator working on the principle of "impact and compression". The milling characteristics includes decortication efficiency, percentage of husk, percentage of broken kernels and output capacity was evaluated at the different levels of moisture content, i.e., 8%, 10%, 12%, 14% and 16% (w.b.) and feed rates, i.e., 12 g/stroke, 14 g/stroke, 16 g/stroke, 18 g/stroke and 20 g/stroke. The moisture content as well as feed rate significantly (P<0.05) affected the decortication efficiency, percentage of husk as well as brokens and output capacity. Decortication efficiency was initially increased and then decreased and opposite nature was found for the percentage of husk. Both percentage of broken kernels and output capacity decreases with the increase in moisture content, while output capacity increases with the increase in feed rate and brokens decreases with the increase in feed rate of wild apricot pits.

Keywords: wild apricot pit, milling characteristics, decortication efficiency, moisture content, husk percentage, broken percentage, output capacity

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1 Introduction

Apricot (*Prunus armeniaca* L.) is an important temperate fruit and perishable in nature. Each and every part of apricot is either consumable or usable as ingredients in different health and food products. Globally, apricot is grown with its two cultivars, sweet apricot and wild or bitter apricot.

The sweet apricot has its origin in Armenia followed by Iran. Turky, Iran, Italy, France, Pakistan, Spain, China and USA are leading producers of apricot. In Asia, apricot was firstly cultivated in northeastern China. Wild apricot appears to be indigenous to India, in which apricot is grown commercially in the hills of Himachal Pradesh, Jammu and Kashmir, Uttarakhand, Uttar Pradesh and to a limited extent in north eastern hills and in Nilgiris. In Uttarakhand sweet apricot is locally known as *Khubani* and wild or bitter apricot is familiar with the local name as *chullu* or *chulli* and *Zardalu* in Uttarakhand and Himachal Pradesh, respectively[1].

Global production of fresh apricot is between 2.2 and 2.7 million tons per year. Sweet and wild apricots are cultivated in Uttarakhand in about an areas of 9 100 hectares with the annual production about 30 576 tons and mainly includes cultivated verities of wild apricot, which are located in Sharmagz Kaisha, Moorpark, Turkey, St. Ambrose are the most[2].

Wild apricot kernel is a rich source of oil (54.21%), protein (17.75%-22.56%), carbohydrate (21.16%-35.26%),

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crude fibre (0.84%-4.71%) and dietary fibre (6.03%-22.24%). Its kernel oil is a rich source of unsaturated fatty acids (94.4%), oleic acid (66.2%) and linoleic acid (28.2%). High amount of monounsaturated and polyunsaturated fatty acids present in wild apricot oil makes it effectual massage oil for aged and dry or irritated skins[3]. It has ability to penetrate the skin and does not produce oily skin. If warm apricot oil with a pinch of common salt is massaged on chest it gives relief from acidity. Kernel oil is also used as treatment of gynaecological disorders, skin hyper pigmentation, headache, backache, jointsache and rheumatic pain. The kernel oil is used in the form of eardrops for inflammation and tinnitus, and for treatment of skin diseases. Due to its medicinal value, there is an unprecedented demand for the oil in recent years. Wild apricot oil containing tocopherols (630 μg/g) can be used in many cosmetic preparations[4]. Sweet apricot kernels are mainly consumed as an important source of dietary protein, oil, fibre, and also these are used as cheap substitute for almonds in pastries, dry fruits and confectionery. The kernels are used as dried nuts and in the production of oils, benzaldehyde, cosmetics, active carbon, and aroma perfume[5].

Apricot harvesting and pit decortication/shelling are still carried out manually in India, which results in increased cost and processing time for kernel extraction. Manual breaking of stones to separate kernels for oil extraction through traditional *kohlu* (oil expeller) is tedious and time consuming. Therefore, a mechanized cracking and handling unit is required to save the time and labor. As the decortication process is the most critical and delicate step for achieving high-quality kernels and minimization of brokens, the effect of the various parameters on mechanized post-harvest processing must be known[6].

Milling properties of wild apricot pits have direct and great influence on its commercial value. The term "Shelling efficiency" is the amount of the pits shelled and yields kernel which is used for further processing. The milling quality was judged by high shelled kernel yield and minimum brokens.

Keeping in view all the above points, the present investigation has been taken up with the following objectives: 1) to study the effects of moisture content and feed rate on milling characteristics, and 2) to study the effects of moisture content and feed rate on output capacity of the sheller/decorticator.

2 Materials and methods

2.1 Materials

The experiments were conducted on a wild variety of apricot pit grown in Uttarakhand. The pit samples were collected from the College of Forestry and Hill Agriculture Ranichahri, Distt-Tehari, Uttarakhand. The initial moisture content of wild apricot pit was found to be (12.5±0.5)% (w.b.). The pit was cleaned to remove the foreign material like plant leaves, dust, mud balls, stones, etc. Size grading near to uniformity improved the decortication characteristics considerably and reduced the breakage of the kernels[7]. Cleaned samples were graded properly using wild apricot pit size grader developed by AICRP on PHT, G. B. Pant University of Agriculture & Technology, Pantnagar, U.S. Nagar, India, Pantnagar centre, which is in accordance with the study by Lestienne et al.[7] for two cultivars of millet. Graded pits were stored properly in gunny bags or metallic container for further experiments of decortication.

2.2 Moisture treatment

The average moisture content of the wild apricot pits was found to be 12.0% (w.b). The moisture content of samples was determined by air convection oven drying at (103±2)°C until a constant weight was reached[8]. The selected levels of moisture content were lower as well as higher than the initial moisture content (w.b.) of pits during the experimentation. The desired moisture content of wild apricot pit samples was determined using the method recommended by Olaniyan and Oje[9]. In this method, the wild apricot pit samples at desired five moisture levels were prepared by soaking the pits in required quantity of water calculated by Equation (1):

$$W_2 = W_1 \times \left[\frac{M_1 - M_2}{100 - M_1}\right] \tag{1}$$

The samples were then stored in the cellophane bags and stored in the freezer at about negative 10°C for 48 h. Later, 24 h before the experiment, the sample was removed from the freezer to allow gradual thawing and allow moisture equilibrium with the sample[9,10]. Lestienne et al.[7] found no significant effect below the moisture content at 8% (w.b.), which not only caused stickiness and lump formation among the grains, but also caused elongation of the kernels to some extent during decortication and milling of millet. The moisture content levels of pits were 8%, 10%, 12%, 14% and 16% (w.b.), respectively.

2.3 Decortication

Properly graded and moisture treated samples of wild apricot pits was used for the decortication. An apricot pit decorticator working on the principle of "impact and compression" and developed by AICRP on PHT, Pantnagar centre was used for the decortication experiment. During experiment the machine parameters such as crankshaft speed and impact clearance was set at optimized level given by Kate et al.[11], i.e., 85 r/min and 1.0 mm, respectively. A sample of 500 g was utilized for each experiment. The output of decorticator was collected and analyzed in different fractions[7,11,12].

2.4 Milling characteristics

The wild apricot pits of different samples having moisture contents before the experiment as 8%, 10%, 12%, 14% and 16 % (w.b.). All samples were subjected to decortication/shelling in decorticator. Feed rates at varying rate (12, 14, 16, 18 and 20 kg/h) were adjusted by setting the metering mechanism of decorticator fitted at the bottom of the feed hopper. A sample size corresponding to 500 g of raw wild apricot pits fed to the decorticator has fixed operating parameters. The following milling parameters were calculated using the formula given below[13-16].

2.4.1 Decortication efficiency

The overall efficiency of the decortication was calculated by Kupritz formula, by the following expression[11,17]:

$$\eta(\%) = \text{coefficient of decortication } (E_d) \times \text{coefficient of wholeness of kernel } (E_{wk}) \tag{2}$$

Where the coefficient of decortication:

$$E_d(\%) = 100\left(1-\frac{n_2}{n_1}\right) \tag{3}$$

The coefficient of wholeness of kernel:

$$E_{wk} = \frac{k_2-k_1}{(k_2-k_1)+(d_2-d_1)+(m_2-m_1)} \tag{4}$$

where, η = overall decortication efficiency, %; E_d = coefficient of decortication, %; E_{wk} = coefficient of wholeness of kernels; n_1, n_2 = amount of undecorticated pits before and after decortication, respectively, g; k_1, k_2 = amount of whole pits after and before decortication, respectively, g; d_1, d_2 = contents of broken kernels before and after decortication, respectively, g; m_1, m_2 = weight of decortication waste before and after decortication, respectively, g.

2.4.2 Broken kernel percentage[13,14]

$$B_r(\%) = \frac{\text{Weight of broken kernels}}{\text{Weight of total kernel}} \times 100\% \tag{5}$$

2.4.3 Husk percentage[13,14]

$$H(\%) = \frac{\text{Weight of husk after decoortication}}{\text{Weight of sample}} \times 100\% \tag{6}$$

2.4.4 Capacity[15]

$$\text{Output capacity (kg/hr)} = \frac{\text{Weight of decorticatied material collected from chute}}{\text{Time required for decortication}} \tag{7}$$

The analysis of variance (ANOVA) tables were generated for each of the response functions. Tukey's Honestly Significant Difference (HSD) test was performed: for those responses data for which ANOVA was significant, and to determine differences between the means by using SPSS 16.0.2, August, 2013.

3 Results and discussion

3.1 Effects of moisture content and feed rate on decortication/shelling efficiency

Decortication efficiency, the extent to which the whole wild apricot pit was decorticated, was obtained by varying the moisture content from 8% to 16% (w.b.) at an increment of 2% (w.b.) for different levels of feed rates (12 to 20 g/stoke). ANOVA (Table 1) showed that there was a significant effect of moisture content as well as feed rate on decortication efficiency of wild apricot pit (P<0.05, F_{cal}>F_{tab}). The values of decortication efficiency at 8% and 12% moisture content were significantly (P<0.05) different from 10%, 14% and 16% moisture contents at feed rate of 12 g/stroke and

16 g/stroke (Table 2). Decortication efficiency at feed rate 14 g/stoke was significantly (P<0.05) different than those at 12, 16, 18 and 20 g/stroke at all levels of moisture contents. The amount of decortication efficiency increased when the moisture content as well as feed rate was increased up to 12 g/stroke and 14 g/stroke, respectively; and again decreases with increase in both, which is in accordance with the study by Mohapatra and Bal[18] for rice. Similar results were also obtained by Shobana et al.[19] and Dharmaraj et al.[16] for milling characteristics of decorticated finger millet, and Lohani et al.[12] for milling characteristics of polished barnyard millet. During experiment, maximum efficiency (qualitative and quantitative) was 78.69% while minimum was 62.69%.

Figure 1a shows the combined effect of moisture content and feed rate on the shelling efficiency of the wild apricot pits. It is found that the decortication efficiency initially increased with the increase in moisture content from 8% up to 12% (w.b.) with all the feed rates

Table 1 Two–way ANOVA results for the effects of moisture content and feed rate on milling characteristics of wild apricot pit

Source of variation	Sum of squares	DF	Mean square	F	P value
Decortication efficiency					
Moisture content	98.5059	4	24.6264	11.0871	0.0001*
Feed rate	384.0061	4	96.0015	43.2208	0*
Error	35.5389	16	2.2211		
Total	518.0510	24			
Percentage of Husk					
Moisture content	26.6168	4	6.6542	12.0621	0.0001*
Feed rate	30.1309	4	7.5327	13.6547	0*
Error	8.8265	16	0.5516		
Total	65.5743	24			
Percentage of brokens					
Moisture content	373.4665	4	93.3666	56.146	0*
Feed rate	133.8667	4	33.4666	20.1251	0*
Error	26.6068	16	1.6629		
Total	533.9401	24			
Output capacity					
Moisture content	319.9016	4	79.9754	146.6362	0*
Feed rate	749.0696	4	187.2674	343.3579	0*
Error	8.7264	16	0.5454		
Total	1077.6976	24			

Note: * significant at 5% level of confidence.

Table 2 Milling characteristics of wild apricot pits at different moisture content levels and feed rates

Feed rate (g/stroke)	Moisture content/%, w.b.					Significance level
	8	10	12	14	16	
Shelling efficiency/%						
12	67.24±1.69^{a}	74.04±5.11^{b}	78.69±9.76^{c}	73.33±4.40^{b}	71.85±2.92^{b}	**
14	73.42±4.49^{b}	75.67±6.74^{b}	76.39±7.46^{bcd}	74.23±5.30^{bc}	71.25±2.32^{bce}	**
16	63.79±5.14^{c}	68.00±0.93^{d}	69.78±0.85^{de}	67.96±0.97^{de}	65.41±3.52^{cde}	**
18	64.48±4.45^{ac}	65.38±3.55^{acd}	68.28±0.65^{acde}	67.23±1.69^{acde}	64.00±4.93^{acde}	**
20	62.69±6.29^{ac}	64.00±4.93^{ac}	65.96±2.97^{acde}	67.00±1.93^{acde}	63.09±5.84^{acde}	**
Husk percentage/%						
12	66.00±3.70^{adc}	64.59±2.29^{adc}	61.36±0.94^{ace}	63.89±1.59^{adc}	64.00±1.70^{adc}	**
14	65.30±3.00^{ad}	64.01±1.71^{a}	61.06±1.24^{ac}	61.85±0.45^{ac}	63.02±0.72^{adc}	**
16	62.50±0.20^{abc}	63.45±1.15^{a}	60.40±1.90^{ac}	61.10±1.20^{abc}	62.91±0.61^{ab}	**
18	61.95±0.35^{ab}	62.80±0.50^{a}	60.07±2.23^{a}	61.00±1.30^{ab}	62.08±0.22^{a}	**
20	60.53±1.77^{ab}	61.78±0.52^{ab}	60.00±2.30^{a}	60.92±1.38^{ab}	61.00±1.30^{ab}	**
Broken percentage/%						
12	28.70±12.24^{c}	21.56±5.8^{bfe}	18.13±2.37^{abd}	15.26±0.5^{a}	13.84±1.92^{ae}	**
14	24.69±8.94^{e}	18.23±2.47^{bfgc}	15.45±0.31^{abfc}	13.87±1.89^{a}	12.06±3.7^{a}	**
16	22.49±6.73^{efc}	17.02±1.26^{bfc}	14.19±1.57^{abfc}	13.05±2.71^{a}	11.13±4.63^{a}	**
18	18.74±2.98^{fc}	15.96±0.2^{bfc}	13.65±2.11^{abfc}	12.06±3.7^{a}	9.96±5.8^{af}	**
20	17.06±1.30^{bfch}	14.08±1.53^{bfc}	12.08±3.68^{abfc}	11.89±3.87^{a}	8.78±6.98^{af}	**
Capacity of sheller/kg·hr^{-1}						
12	72±3.86^{a}	70.6±5.26^{ab}	68.5±7.36^{b}	66±9.86^{c}	65±10.86^{c}	**
14	77±1.14^{b}	75.5±0.36^{bc}	72.3±3.56^{d}	69±6.86^{e}	67±8.86^{ec}	**
16	81±5.14^{c}	77±1.14^{e}	75±0.86^{e}	72.4±3.46^{f}	70.5±5.36^{f}	**
18	85.5±9.64^{d}	82±6.14^{f}	79.5±3.64^{g}	76±0.14^{h}	74.6±1.26^{i}	**
20	90±14.14^{e}	86.5±10.64^{g}	84±8.14^{h}	80.2±4.34^{j}	79.5±3.64^{j}	**

Note: Values are (Mean±SD) of three replicates. Values followed by the same letter in the same row and column are not significantly different (P<0.05).
** and * means significant at 1% and 5% significance level, respectively.

of the pits and then decreased with the increase in moisture content from 12% to 16% (w.b.). This is because the cracking strength and rupture force of the pits decreases with increase in moisture content, while the decrease may be a result from softening the walnut at higher moisture content, but at higher moisture content the splitting of the kernels takes place and hence the efficiency decreases due to decrease in coefficient of wholeness of kernel. Similar conclusions were also drawn by Braga et al.[20] for macadamia nut; Guner et al.[21] for hazelnut; Koyuncu, et al.[22,23] and Aktas et al.[24] for almond; and Sharifian and Derafshi[25]; Altuntas and Erkol[10] for walnut. Also the Decortication efficiency initially increases with the increase in feed rate as the broken kernel percentage decreases with it, but further increase in feed rate amount of undecorticated pits in output was increased and hence the efficiency decreases.

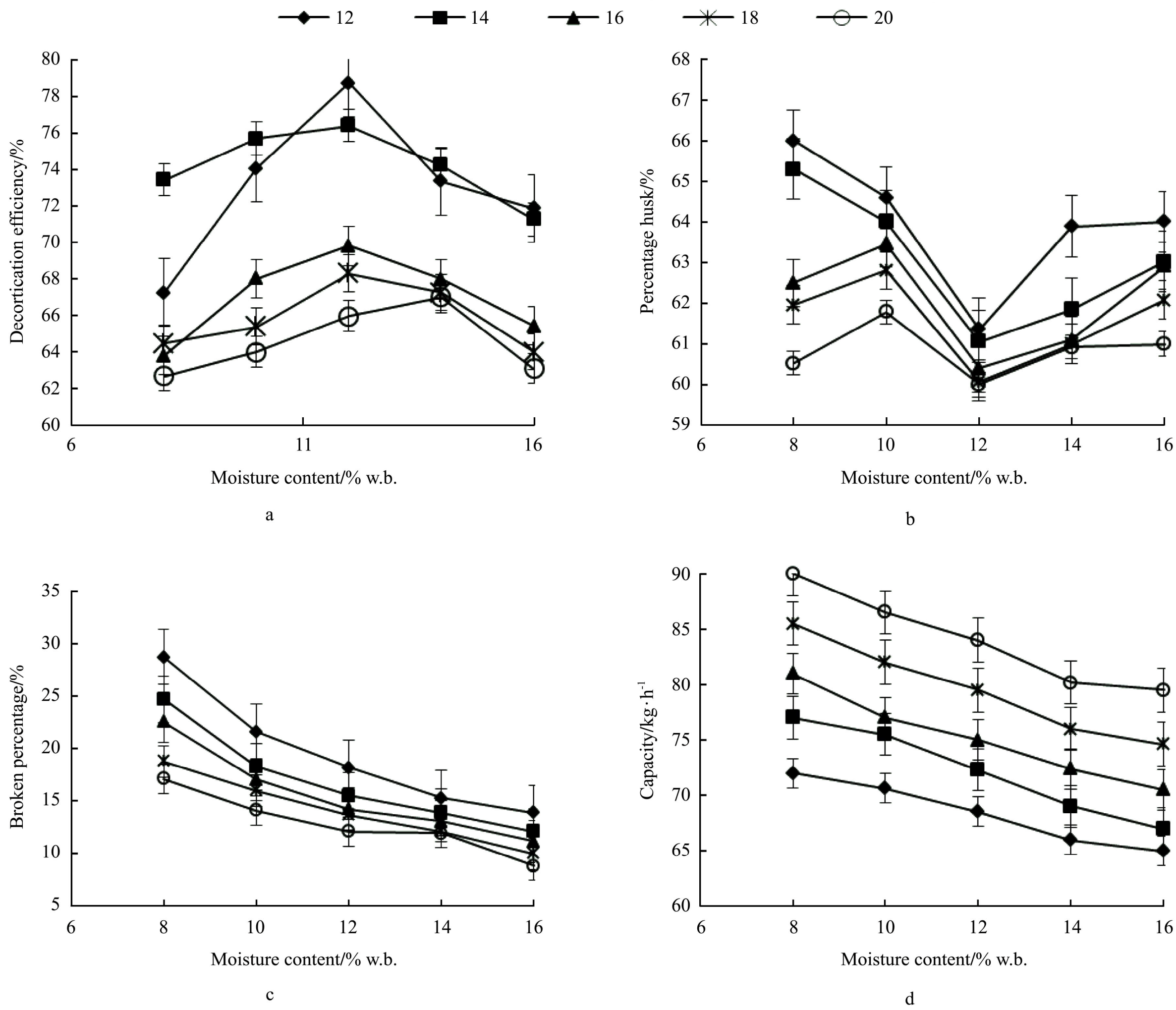

Figure 1 Effects of moisture content and feed rate on the decortication efficiency (a), percentage of husks (b), percentage of brokens (c), and capacity (d), respectively

3.2 Effects of moisture content and feed rate on percentage husk

Percentage husk obtained after the decortication of wild apricot sample varied with moisture content and feed rate of the pits. The ANOVA analysis showed that there was a significant effect of moisture content as well as feed rate, on percentage of husk obtained after the decortication of wild apricot pit (P<0.05, $F_{cal} > F_{tab}$) (Table 1). The values of husk percentage at 12% moisture content was significantly (P<0.05) different from 8%, 10%, 14% and 16% moisture content at 12 g/stroke feed rate and the relation is failed for other levels of feed rate (i.e., 14, 16, 18 and 20 g/stroke) (Table 2). The percentage of husk at 14 g/stroke was significantly (P<0.05) different with 16, 18 and 20 g/stroke feed rate, while no significant with 12 g/stroke feed rate at the moisture content level of 8% and 16% (w.b.) was found. Also the percentage of husk continuously decreases with increase in feed rate while it initially decreases (up to 12% (w.b.) moisture content) and then increases with the increase in moisture content (w.b.) of the wild apricot pits. Similar results were also obtained by Shobana et al.[19] for milling characteristics of decorticated finger millet and Dharmaraj et al.[16] during process optimization of finger millet decortication.

The combined effects of moisture content and feed rate on the percentage of husk obtained at the outlet after the decortication of wild apricot pits samples were shown in Figure 1b. It is observed that percentage of husk decreased with the increase in feed rate, which is because amount of undecorticated pit obtained during the decortication increases with the increase in feed rate. Also it initially decreases up to 12% moisture content and then again increases with further increase in moisture content during all the levels of feed rates. This is because comparatively cracking strength of dried pit was more than the moist pit hence some pits remains undecorticated; there is not observable effect of increased moisture up to 12%, but then percentage husk increases due to decreasing in cracking strength decortication.

3.3 Effects of moisture content and feed rate on percentage of brokens

Percentage of broken kernels, the extent to which the breakage of the wild apricot kernels obtained during the decortication of pit varied with the moisture content from 8% to 16% (w.b.) at an increment of 2% (w.b.) at different feed rates levels (12 to 20 g/stoke). The ANOVA analysis showed that there was a significant effect of moisture content as well as feed rate on percentage of broken kernels obtained after the decortication of wild apricot pit (P<0.05, $F_{cal} > F_{tab}$) (Table 1). It was found that the broken percentage at 8% during feed rates of 12, 14, and 16 g/stroke was significantly (P<0.05) different from that at 10%, 12%, 14% and 16% (w.b.) moisture content (Table 2). Also the broken percentage at 10% moisture content and 12 g/stroke feed rate was significantly (P<0.05) different than that at all other moisture content levels and feed rates. It shows that the percentage of brokens decreases with increase in both moisture content (w.b.) and feed rate of the wild apricot pits (Table 2). Similar result was found by Shobana et al.[19] during milling characteristics of decorticated finger millet and Lohani et al.[12] during milling characteristics of polished barnyard millet.

The effects of moisture content and feed rate on the percentage of broken kernels obtained at the outlet after the decortication of wild apricot pits samples are graphically represented in Figure 1c. It shows that the broken kernel percentage continuously decreases with the increase in both feed rate and moisture content during all the ranges of experiment, which is because extra cracking force was exerted on the individual pit at lower feed rate and hence the broken of kernel takes place. Similar result was obtained by Dharmaraj et al.[16] during process optimization of finger millet decortication.

3.4 Effects of moisture content and feed rate on output capacity

There was variable effect of moisture content (w.b.) and the feed rate of wild apricot pit on the output capacity of the decorticator used for the decortication. The ANOVA analysis showed that there was a significant effect of moisture content and feed rate on output capacity obtained after the decortication of wild apricot pit (P<0.05, F_{cal}>F_{tab}). It shows that with increase in feed rate the output capacity increases while with increase in moisture content of the wild apricot pit output capacity decreases gradually (Table 2). The output capacity of the decorticator obtained at the all levels of feed rate was significantly different from each other at all the moisture content levels. Also the output capacity obtained at all the moisture content levels was significantly different from each other at the feed rate of 18 g/stroke and 20 g/stroke.

Figure 1d shows the combined effects of moisture content and feed rate on the output capacity of decorticator all the samples wild apricot pits. It is observed that output capacity of the decorticator increases with increase in feed rate while decreases with increase in moisture content of the wild apricot pits. This is because feed rate increases the input of decorticator and has direct effect on the amount of output, while as bulk density of wild apricot pits increases with increase in moisture content and due to this blocking or chocking of the machine takes place, also it indirectly affected on the feed rate, hence the output capacity decreases[15,17].

3.5 Effect of decortication process parameters on food quality

As decortication of wild apricot pit is the just shelling process for seperation of outer pod like husk from the kernel used for food, pharmaceutical, etc. There is no any direct contact of soaked (moisture treatment) water and decortication mechanisam and hence no any physical and chemical disturbance to the kernel, hence quality of kernel does not have any adverse effect.

4 Conclusions

The wild apricot pits can be decorticated in decorticator working on the principle of “impact and compression”. For obtaining optimum milling characteristics, i.e., decortication efficiency, percentage of husk, broken kernels and output capacity of the decorticator, moisture content at 14% (d.b.) and feed rate at 18 g/stroke can be recommended. Moisture content has more critical effect on decortication efficiency and percentage of broken than feed rate, while feed rate has more effect on percentage of husk and output capacity followed by moisture content.

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