

Design And Fabrication Of A Prototype Decorticator To Remove Seed Coat Of Black Cumin (*Nigella Sativa*)

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ABSTRACT: Black cumin (*Nigella sativa*) seed is very important and widely used seed in traditional medicine. Since, black cumin seeds have been enveloped with a thick seed coat in black color, potential for commercial applications has been restricted. Hence, a prototype decorticator was designed and developed to remove the seed coat by applying abrasion and friction principle. The machine consists with a cylinder, axle and flat bars. Four flat bars have been welded 150mm apart in symmetrical manner on the axle. Distance between two flat bars are 25mm at an angle of 60°, however, the angle of two flat bars should be in counter directions as well as in non-geometric way. Therefore, this mechanism imparts adequate push with necessary energy to the watery black cumin seeds in counter current manner when axle is rotating at the speed of 821rpm. Thus, watery seeds are pushing as a counter current streams from opposition directions and smashing each other with an adequate energy, resulting to create friction and abrasion actions between black cumin and black cumin seeds as well as between seeds and inside surface of the cylinder. Due to acting upon these two forces over the seed coat, end result was detaching the seed coat from the cotyledons. Results revealed that decortications machine was capable to remove 85% of the seeds coat of the seeds by applying friction and abrasion principle. Best results were obtained when seeds were soaked in cold water for 5 minutes prior to ingestion them into the decorticator.

KEY WORDS: Black cumin, Cold pressing, Decorticator, FFA, *Nigella sativa*

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I. INTRODUCTION

The purpose of this research was to design and fabricate a prototype seed decorticator to remove the seed coat of black cumin seeds with a view to extract light color oil. Currently, seeds are cold pressed without removing seed coat and getting dark brown colour oil which takes long time for sedimentation because, there is no mechanical device at present to remove seed coat of black cumin seeds. Hence scope of this study is to develop a user friendly, low cost and efficient device (prototype) to remove the seed coat of black cumin seeds. The study was primarily focused on how to mechanize conventional decorticating methods to suit the requirement of black cumin seeds, because black cumin seeds are so small, delicate and subject to damage when excessive force is applied. Thus, the working principle of conventional device called “motor and pestle” which currently being used by the rural folk to de-husk the paddy grains, was extensively studied and found many positive points that are favorable for decorticating of the black cumin seeds. After scrutinizing the pounding process of paddy, found that friction and abrasion between grain and grain as well as between surface of the motor and pestle are caused for removing of the paddy husk. Thus, these two working principles were taken into consideration in designing and developing the prototype machine. Thereafter, a decision was made to build a machine based on a cylinder with rods.

II. MATERIALS AND METHODOLOGY

Basic components that are used in fabrication of the prototype design to remove seed coat of black cumin seed are given in the Table 1.

Table 1: Design components of the prototype decorticator

Item	Description	Specification
01. Feeding hopper	Raw material	Steel
	Capacity	4-5kg
	Dimension	200×200×200mm(L×W×H)
02. Grinding chamber	Cylinder-Raw material	Steel
	Capacity	2.5kg
	Dimension	450mm×,110mm(L×d)
	Shaft	Steel 200mm (L)
03. Pressure system	Helical spiral	Steel 300mm (L)
	Pressure plate	Steel 118mm (d)
	Spin	Steel 210mm (L)
04. Pulley system	Two pulleys	150,88mm (d)
	Belt	A 25
	Motor	Rev-1400r/min

2.1 Different components of the decortication machine

2.1.1 The frame

The frame (750×350×675mm) is made of steel tubes welded together (Fig. 1) to withstand the weight of cylinder, electrical motor and damped black cumin seeds. The cylinder was horizontally welded to the frame at the both ends of it and the main axel/shaft which was running through the middle of the cylinder was mounted onto the frame using ball bearings. One end of the cylinder, close to the feeding hopper was covered with a steel flange. The motor is mounted on the bottom of the frame closer to the ground level. The motor was placed in incline manner on the shelf that has also attached to the frame in order to adjust the motor with the driven pulley. This mechanism was an ideal application with respect to the adjustment of the driven pulley on the vertical axis along with the driving pulley coupled with the motor. Further, this mechanism would facilities to adjust the tension of the belt as it inadvertently tends to stretch with the time.

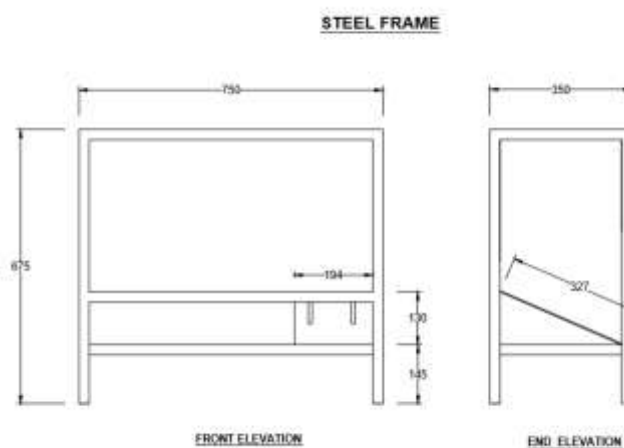


Figure 1: Front View Of The Frame

2.1.2 The Feeding Hopper

Damped seeds are fed into the hopper (200×200×200 mm) which has the capacity to hold 4-5 kg (Fig 2). The hopper is also made up of with steel and hopper is similar to a square shape funnel and it is fitted 130mm above the cylinder in order to facilitate the seed movement due to gravity into the cylinder smoothly. There is also feed regulator to control the rate of seeds feeding into the decortivating section (Cylinder with the shaft) of the machine. Finally, seeds are moving into the decortivating section of the machine through the feeding tube (130mm & φ 25mm).

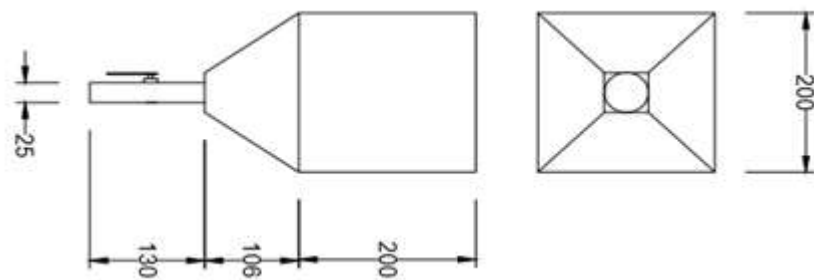


Figure 2: Side And Top Elevations Of The Hopper

2.1.3 The Cylinder and shaft

The Cylinder (450mm length, 110mm diameter), the cylinder ends, round shaft (870mm length, 15mm) with helical spiral (300mm length, 90 mm circular diameter) are made of steel and galvanized to meet the hygienic standards. One end of the cylinder (closer to the hopper) is welded to a steel flange and the other end is opened, from where the decorticated seeds are to be removed. The round shaft or the axel running through the cylinder and ends of the shaft are mounted on the frame by the support of bearings. In this bearing grease nipples are also fitted to increase the revolving efficiency of the axel.

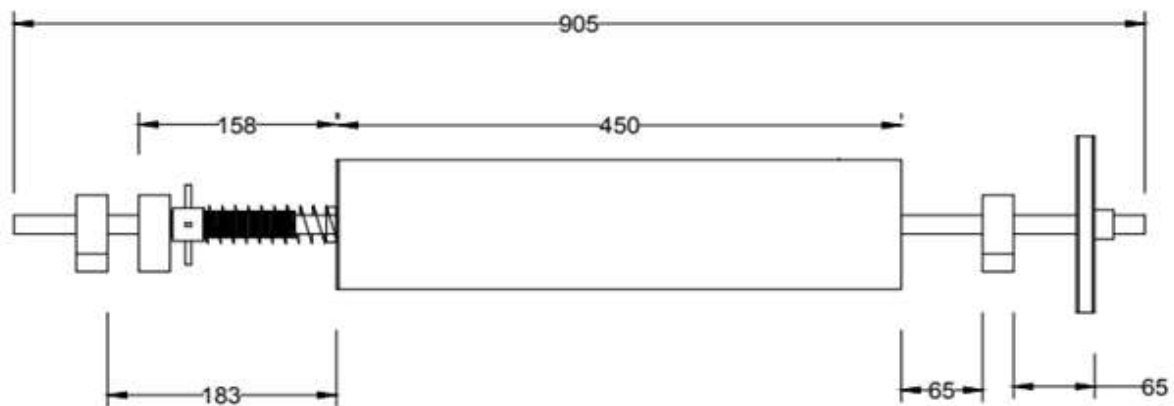


Figure 3 Front Elevations Of The Cylinder And The Shaft

On the shaft a helical spiral is attached geometrically (Fig 4) with a specific distance (20mm) between two spirals. The role of helical spiral is to push the damped seeds towards the flat bars continuously. This movement is essential to pound the seeds inside the cylinder as well as to separate the seed coat from the kernel. Seeds are needed to rub against the wall of the cylinder to generate friction which will cause for decortications. Friction between seeds and seed themselves also facilitates to the decortications process. Therefore 4 flat bars are welded to the rotating round shaft starting from the end of the spiral as shown in Fig 4.

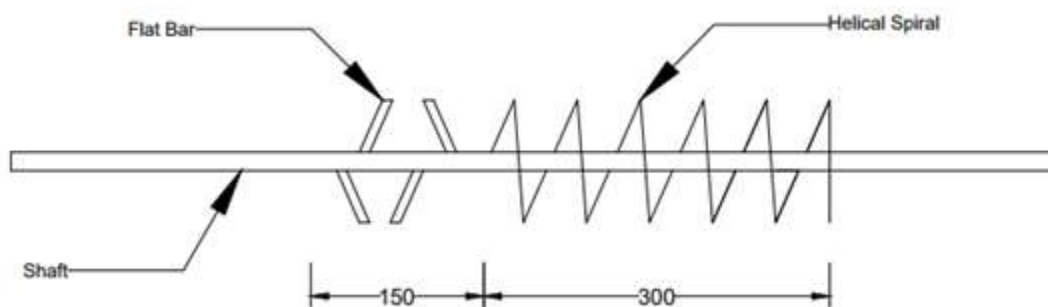


Figure 4: Shaft With Spiral And Flat Bars

When the shaft is rotating at a considerable speed (821rpm), flat bars press over the seeds and friction that generates between the surface of the seed coat and the surface of the flat bar removes the seed coat. According to the theories of friction, whenever the surface is getting rough, intensity of generated friction is getting higher. According to the Karpenko et al (2001) ^[1] progress of friction models between rough surfaces closely correlates with advances in experimental investigations of contact forces and theoretical modeling of surface ^[1]. Images of black cumin seeds taken as section wise, three different parts of the seed from the Scanning Electron microscope show that surface of black cumin seeds are rough and after decortication a smooth surface was observed. All real and contact surfaces are rough, and any calculation of the frictional force between surfaces should be taken into account of this roughness and number of contact points, contact area and contact pressure, and the friction coefficient itself, are reasonable to the ultimate frictional force ^[2]. Therefore, it gives evidence to show that there is a potential to decorticate this type of seeds in the aspect of morphological characteristics of the seeds.

2.1.4 Pressure plate with spin

Opening end of the cylinder is faced with a pressure plate (118mm diameter) which is made of steel and circular in shape, similar size with the round end of the cylinder. This pressure plate is adjusted by a spin (210mm length) which is attached to a handle. The spring is compressed on a treated steel pipe to get its spin. Pressure plate is freely movable along with the axis as it shouldn't rotate with the shaft together. Otherwise pressure plate won't be adjusted by the spin. When handle is rotated which compresses the pressure plate towards the opening end of the cylinder using the spin, pressure is applied inwardly to the cylinder where seeds are rubbed against each other as well as over the wall of the cylinder by the flat bars. According to the alignment of this pressure plate, pressure is exerted externally into the flow of seeds which are coming out from the cylinder. When the pressure exerted within the cylinder is greater than the pressure exerted from outside (from spin and pressure plate) seed lot will flow out ward. If not seeds will retain inside the cylinder rubbing over each other. This method of pressuring used to control the decortivating speed of the seeds. The sketch diagram pertaining to the function of the decorticator is shown in Fig 5.

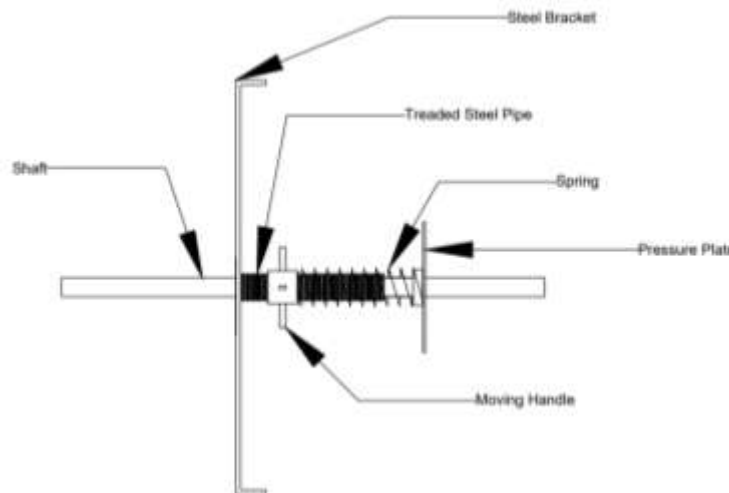


Figure 5: Pressure Plate With The Shaft

2.1.5 External parts of the decorticator

Two pulleys one is larger (150mm diameter) than the other and the driven belt (A 25) is connected on a vertical posture. Smaller pulley is fitted to the motor while the larger one is coupled with the shaft (fig 6). The distance between two pulleys is approximately 350mm. When the electrical energy is supplied from the motor (Fig 7), small pulley ($\phi 88\text{mm}$) starts the rotation and that rotational energy is transmitted to the large pulley via belt. Then the spiral and flat bars welded to the shaft will start revolving. At the same time seeds are entered into the cylinder and with the rotational movement, seeds are rubbed each other while seeds are pushed forward by the spiral. With the friction generated among seeds, seed coats are detached from the kernel.

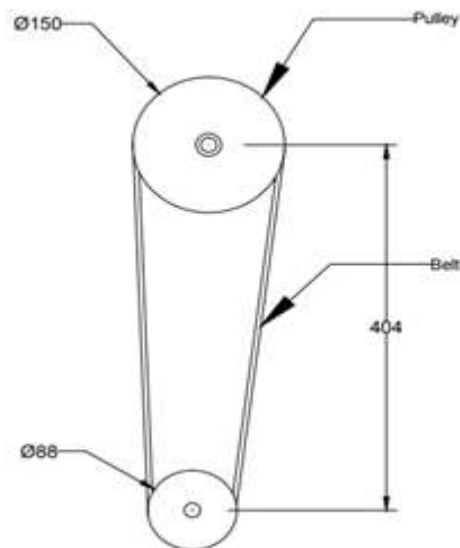


Figure 6: Pulley System Of The Device

Single phase induction motor is connected to the shelf which attached to the frame and technical specifications of it are given below.

- Model – YC90S/4
- Power -1HP (0.75kW)
- Power supply -230V, 7.4A, 50Hz
- Weight – 18kg
- Revolution- 1400r/min



Figure 7: Single Phase Induction Motor

Special feature of this design is the shelf which is attached to the frame is in slanted manner to facilitate the tightness of the belt when it gets slack.

Seed chute

Pounded seeds which contain seed coat, cotyledon and whole seed fall down through a seed chute (300mm height) which will be collected from outside as shown in fig 8.

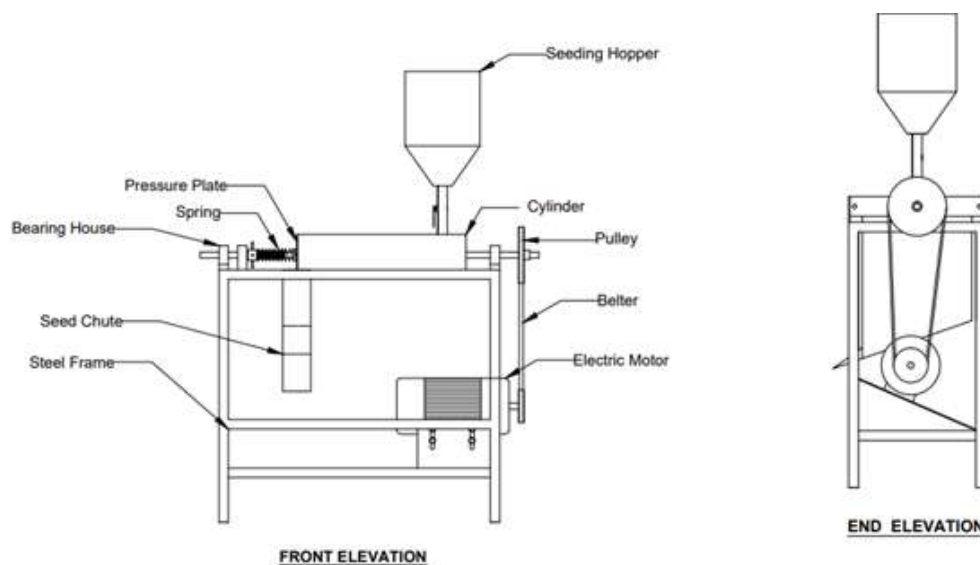


Figure 8: Sketch Diagrams Of The Prototype Design



Figure 9: Image Of Final Decortication Machine

2.2 Determination of physiochemical properties of black cumin

2.2.1 Nigella oil analysis

Oil extraction was carried out by cold press method for both types of black cumin Ethiopian and Indian origins. One seed lot was decorticated and subjected to extraction while other lot was fed into extraction without decortication. Hence two types of extracted crude oils were analyzed for Free Fatty Acid (FFA; as 5 oleic acid), peroxide value (PV; meq O₂/kg oil), Iodine value (IV; Wijs) and specific gravity according to AOAC (1990)^[3].

2.2.2 Free Fatty Acid value

Depending on the expected acid value, 0.5g of the test oil sample was used for the analysis with neutralized solvent and indicator. Then the solution was titrated against potassium hydroxide while swirling taking end point as persistent colour change for 15 seconds minimum. Results were determined in triplicates for both varieties Indian and Ethiopian prior to decortication and after decortication of black cumin seeds.

2.2.3 Peroxide value

Erlenmeyer flask was rinsed with glacial acetic acid prior to use in order to ensure that flask does not contain any oxidizing or reducing substances. 5.0 g of crude oil sample was measured into the Erlenmeyer flask and test sample was dissolved in 50 ml of glacial acetic acid/isooctane solution by gentle swirling. Then 0.5 ml of saturated potassium iodide solution was added and closed Erlenmeyer flask was stirred by using a magnetic stir without creating a large vortex for 60 seconds. Flask was opened immediately after stirring and 100ml of deionized water was added followed swirling. Immediately liberated iodine was titrated with 0.01N Sodium thiosulphate standard solution from yellow orange to pale yellow and thereafter 0.5ml of starch solution was

added, from violet to colourless titration was preceded and as soon as solution is colourless for 30 seconds titration was stopped. A blank was carried out which should take not more than 0.1ml of thiosulphate. Otherwise saturated potassium iodide was replaced. Results were determined in triplicates for both varieties Indian and Ethiopian prior to decortication and after decortication of black cumin seeds.

2.2.4 Iodine number

Accurate 0.13g of test oil sample was measured into a glass scoop and it was laced in 500ml of volumetric flask. Then solvent mixture of glacial acetic acid 20ml and chloroform 20ml was added into the flask and mixed well. Then 25ml of Wiji reagent was pipette out into the flask and stoppered and swirled solution was kept in dark for I hour. At the end of the reaction time 20ml of potassium iodine and 150 ml of deionized water were added and swirled well. Solution was titrated against 0.1N Sodium thiosulphate standard solution from yellow colour due to iodine has almost disappeared, and thereafter few drops of starch solution were added, titration was continued until the blue colour just disappeared after vigorous shaking and volume was recorded. Concurrently a blank was carried out and volume of thiosulphate was recorded.

2.2.5 Specific gravity

Weight of well dried pycnometer was measured using the analytical balance and after removing the water, Pycnometer was cleaned, well dried again. Then pycnometer was filled with the oil sample and accurate weight was measured using the analytical balance. Again, pycnometer was cleaned and well dried, filled with distilled water and accurate weight was taken. Calculations were done base on these accurate weights and respect to two varieties of black cumin and the oil extracted prior and after the decortication process were also analyzed similarly.

2.2.6 Refractive index

The brix meter was cleaned with distilled water and wiped out and a drop of oil was kept on the brix meter. Refractive index was observed through the brix meter (Digital brix meter; ATAGO Pocket PAL-1, Japan)

III. RESULTS

3.1 Effect of wet decortication

Since the morphological characteristics (size, shape) of the black cumin seeds are somewhat similar to sesame seeds, decortications process was carried out as done it for sesame seeds. Thus, the 250g of clean Ethiopian origin black cumin seeds were soaked in clean water at 37°C for 5minutes to loosen the seed coat. (since preliminary trials revealed that 5 minutes soaking time is the optimum to avoid destruction of cotyledons when five time periods such as 5,10,15, 20 & 25 minutes were taken with a view to determine appropriate soaking period). Thereafter decortication was carried out and results pertaining to the efficacy of seed coat removal are given in the Table 2.

And well soaked seeds were fed into the machine and decortication was carried out for 5minutes (5 minutes was the travel time of seeds through the decortication cylinder) and seeds were collected. Three samples (2g) were taken from the output and subjected to determine percentage of decoration. The same stuff was feed back into the machine and again decortication was carried out and percentage of seed coat removal was calculated. Same procedure was reported for four times and results are given in the Table 2.

Table 2 Decortications percentage of black cumin seeds

Term of Decortication	Soaking time	Decortication %
1 st Decortication	5min	48%
2 nd Decortication	5min	55%
3 rd Decortication	5min	64%
4 th Decortication	5min	76%
5 th Decortication	5min	85%

As shown in the Table 2, it is clearly evident that when the numbers of decorticating cycles are increased the decortication percentage also concurrently increases. Decorticated seeds were subjected to pass through a series of sieves (0.075 μ -2.36mm) and according to “passing through” and “retained on” passing through percentage was tabulated in fig 10.

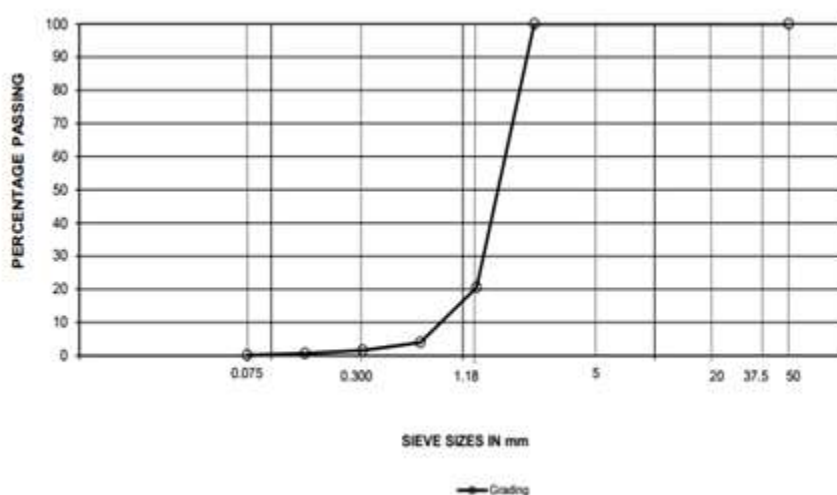


Figure 10. Particle Size Distribution Of Treated Seed Lot



Figure 11: Segregated Categories According To Particle Sizes

As shown in fig11, seed coat was reduced in size further and almost black coloured powder was observed. This implies that decorticated seed coat is further grinded due to the friction and abrasion exerted within the cylinder and it supports the separation of seed coat from the treated batch. Also, cotyledon without seed coat has been segregated separately as shown in the fig 11 and whole seeds and mixed cotyledons are also observed. According to the data given in fig 10 appropriate sieve system with suitable sieve sizes can be analyzed further to separate decorticated seeds from un-decorticated seeds. Seeds retained on 1.18mm sieve size and pass through 2.36mm is the best range to separate decorticated seeds.

3.2 Determination of Physiochemical characteristics of Nigella seed oil

Table 4 physiochemical characteristics of black cumin oil respect to Indian and Ethiopian varieties

Physiochemical characteristics	Cold pressed <i>Nigella sativa</i> oil			
	Indian (before decortication)	(before decortication)	Indian (after decortication)	Ethiopian (After decortication)
Refractive index	1.470		1.475	1.473
Free Fatty Acid (% oleic acid)	8.2 ^a ± 0.25		7.2 ^b ± 0.32	10.6 ^c ± 0.32
Peroxide value (meq O ₂ /kg oil)	36.4 ^a ± 0.88		7.3 ^b ± 0.25	43.0 ^c ± 2.4
Iodine value	122.5 ^a ± 0.55		42.1 ^b ± 1.56	115.1 ^c ± 1.15
Specific gravity	0.9179 ^a ± 0.0009		0.9156 ^b ± 0.0032	0.9233 ^c ± 0.0037

*Data presented as mean values for triplicates replicate ± S.D (n=3). a,b,c,d letters in same raw are significantly different at (p < 0.05) level.

Physiochemical characteristics of *Nigella* seed oils are presented in Table 4. Refractive index of *Nigella* seed oil of both types “Indian and Ethiopian” origins were similar to each other and these findings are in compliance with the results obtained by Tsakins, (2002) [4] for Egyptian black cumin seed oil. At 95 % confidence level

there is no significant difference between oil taken from decorticated and un-decorticated seed in refractive index and the specific gravity of the oil. But significant difference was observed in parameters such as Free Fatty Acid (FFA), peroxide value and iodine value. Highest FFA was resulted in Ethiopian crude oil (10.6) whereas it is comparatively lower than the Indian type. But after decortication a significant difference in acid value was observed and that emphasis that there was a direct impact in decortication process. In industries, most of the time acid value is measured as a quality parameter of seeds and according to ISO 3696 certification maximum acid value that Nigella oil could poses is 35 mg of KOH per gram of oil. Lower acid value as well as poly unsaturated fatty acid profile (61.39 % polyunsaturated in Ethiopian ^[5]) of black cumin oil shows that decortication is a viable process to reduce FFA in extracted oil. Further decortication process facilitates to reduce time taken to sedimentation of the extracted oil and enhance the filtration process too.

The iodine number of 100–120 indicates that Nigella oil is a highly unsaturated oil and suggests that it contains high levels of oleic and linoleic acids. Iodine values of Indian and Ethiopian origin oils are similar to those reported by authors ^{[6][7][8]}. Peroxide value is the most widely used indicator of fat oxidation, as it measures the lipid peroxides and hydroperoxides formed during the initial primary stages of oxidation. Peroxide value of oil is a valuable measure of oil quality and Indian and Ethiopian types resulted 36.4 and 43.0 meq per kilogram of oil respectively. The significant difference of acid and peroxide values observed after decortication obviously makes evidence to show that quality of the oil can be improved through decortication process.

IV. CONCLUSION

Decortication process of black cumin seeds is positively capable with the designed and manufactured prototype device. The mechanized conventional decortication method is ideal for the dehulling process and the developed devise is user friendly, low cost and efficient 85% at this stage which can be improved further. Even more cold pressed oil showed improved physiochemical properties mainly in FFA and peroxide values which emphasis the importance of decortication process of the black cumin seeds.

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