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Developing, Testing And Promotion Of Small Scale Jatropha And Castor Seed Processing Technologies

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Abstract: Some of the prominent barriers for the transition towards Jatropha/caster plants based bio fuels in Ethiopia are technical gaps and lack of awareness about the advantages of the plants oil (especially, the jatropha) beyond the purposes of fences and lack of utilization technologies. In addition, since the seed productions are not yet sufficient and the engine driven presses or big centralized processing facilities are not feasible in rural areas, so that, small scale press, stoves, lamps and soap making systems were designed, developed , tested and used in this project as a live oil expelling, utilization and promotion systems in different parts of Ethiopia. The press powered by a hand and hydraulic jack was made in to simple operating mechanism. Single batch, 450 gram seed, pressing takes 4-5 minutes with the capacity of 1.2 -2 liters oil per hour. A simple stove was modified and adopted to diversity of fuel feed stocks and shows significant improvements of flame height, color and fuel consumption rate with reduced amount of smoke, especially in jatropha and caster bean seeds and pressed cake. The fuel consumption tests of using 0.5 kg of each fuels resulted in total burning time of 1 -1.30 hours, 7-12 minutes boiling time of 10 liter water and measured flame temperature of about 670-800 ^{0}c. In addition, the jatropha crude oil was also utilized in a developed simple stove and lamp, for soap making and also as a fuel in diesel engine, after standard laboratory tests of the oil chemical properties. Thus, this paper presents results of ways of developing, performance tests and promotional aspects of the devices, as low-cost and easy-to-use in the rural areas of developing countries, like Ethiopia.

Keyword: Jatropha Curcas; Castor Seed; Pressed Cake; Press, Stove

1 INTRODUCTION

The escalating price of crude oil in the international market has prompted the Ethiopian government to consider the utilization of bio-fuel, such as jatropha castor bean, etc. Jatropha curcas is a drought resistant perennial tree and the castor, Ricinus communis, is a species of flowering oil plant. Both plants are belonging to spurge family Euphorbiaceae [1], [2]. Jatropha and castor plants grow in Ethiopia, where the country is one of the leading castor producing areas in the world [2], [3]. Both Jatropha and castor plants are non-edible oil-bearing plants, that can be grown on marginal- Lands [2], [4], [5]. Hence, the use of biodiesel from jatropha and castor oil are promising alternative to fossil fuel because they are renewable, and environmentally friendly, and can also be produced locally. However, some of the prominent barriers for the transition towards bio fuels in Ethiopia are technical gaps, lack of utilization technologies and lack of awareness about the advantages of the plants oil (esp. the jatropha oil) beyond the purposes of fences [3]. Conventional industrial technology for the synthesis of biodiesel from vegetable oils, involves isolation of the oil from the seed, refining, and then transesterification [4], [6]. In Ethiopia, however, the productions of the bio fuels seeds are not yet sufficient and the engine driven presses or big centralized processing facilities are not feasible in rural areas. Since 2008, Bako Agricultural Mechanization Research Center (BAMRC) has developed some devices for processing of jatropha and castor seeds. As an important part of production of the plants oil is oil extraction from seed, thus, a hand operated hydraulic press has been developed and used for this project. The batch system press was made in to simple and affordable operation to small holders of the country. Although most of them are institutional and power driven, worldwide, of course, many more experiments are being carried out and versions of seed oil pressing machines are developed for various seed oil processing [4], [6], [7], [8], [9]. Output of plants product, the raw seed, crude oil and pressed cake of the jatropha and castor oil can be used in different ways. The center has developed cooking stoves for the seeds utilization as fuel. The stove is a batch type of cooking gassifier stove with 0.5kg biomass holding capacity. Although, the biomasses and stoves types are different than those used in the current study (except the wood biomass), especially, literature about the utilization of the jatropha and castor seed stoves is limited, but there are various versions of house hold level cooking stoves in the world; plancha stove by [10], a cocking stove result with karanja plant by [11] and sawdust with jatropha fruit coats and sawdust efficiencies were reported in [12]. Since, the objectives of this work were developing of small scale jatropha and castor seed processing and utilization devices, technical performances testing and promotion of the appropriate prototypes for users as a live oil expelling, utilization and promotion systems in different parts of Ethiopia, so that, in addition to the developed press and stove for seed burning, the jatropha crude oil was also utilized in a developed simple a stove, lamp and also for soap making and as a fuel in diesel engine, after standard laboratory tests of the oil chemical properties. Thus, this paper presents aspects of the small scale plant oil processing and utilization devices, as low-cost, easy-to-use oil processing technology it may increase the production of the non edible plant oil for fuel in rural areas, as it also intended to create an interest and awareness of the jatropha and castor local production and utilization, which may help improving the development in the rural areas.

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2. Materials and Methods

2.1 Materials and Equipments

Materials used in this research were matured and dried jatropha and castor seeds. To prevent effect of varietal variation (species) and harvesting date of jatropha seed, unidentified varieties of jatropha seeds from four locations (Ziway-East Shoa, and Bako, Arjo and Sire woredas of Wolega zone) were collected at the same season (time) and separately used as a testing variable. Locally produced types of unidentified varieties of Castor bean seeds were also collected at the same time and categorized in to three types based on their color and size. For testing purposes, dried 180 kg of jatropha and 140 kg of castor seeds were needed for the two main tests (press machine and raw seed stove performance tests) with three replications (average), for the first and the second tests, for more than 5-8hours tests. Extraction machine was batch type hydraulic press made by BAMRC, called '*Bako Press (Bp or Pr)*'. The press was powered by a heavy truck's hydraulic jack of 30 ton capacity. Testing equipments used were digital thermometer (to measure stove temperature), digital scales (to measure weight), stop watch (to measure time), and calibrated breaker (to measure volume). Other equipments used were different plastic bottles, coarse bag, and sieve to retain oil resulted and solid wastes.

2.2 Hydraulic Jack Presses development and performance test

The main important parts of the press, that were determinant in design and developments of the prototype are: cage size, its opening structure, size and its sit, draining parts and its guide, inverted top pistil, hydraulic jack cranking and lowering mechanisms. In addition, the hydraulic jack capacity, cage and frame material and strength selections were also the main steps in the design trials. In its operation, the cage and its internal parts used for holding the seeds, this part is also used to expel the oil out of the seeds by resisting two sides forces from below by hydraulic/screw jack and from the top by pressing pistil. By the two reaction forces against the seeds and the bottom of the hopper, pure oil expels out, leaving cake in the cage (Fig 2.1). After repeated trials and design refinements, three presses arrangements of cage, piston and hydraulic jack operation positions were developed for the test. In the first press, the cage in fixed position and piston in moving position with the jack pistil were in angle position at about 45^0 to the horizontal. The second is also in the same angle, but with piston in fixed position and cage in moving position. In the 3rd arrangement the frame, piston and jack were vertical position with the piston fixed position to the frame at the top and cage in moving position along the jack pistil. Their performance was tested for Jatropha/castor seed oil extraction rate (capacity) and efficiency. The amount of oil extraction was measured in liters per hour (liters/hour) and the amount of seeds processed was measured by the time taken to process 15 kg of seeds (hours per 15 kg). The amount of oil extracted has been measured by the extraction rate, and/or more appropriately by the efficiency. Each test was performed on approximately 450 g of seeds in batch system of three times replications for averaging of the results. Density of Jatropha and the castor seed at 0.91kg/litre and 0.96kg/litre respectively). The efficiency was expressed as the ratio of the amount of oil extracted (in kg) to the theoretical amount of oil (in kg) in the seeds based on the oil content; 38% for Jatropha seed and 50% for castor bean [4].

2.3 Cooking Stove development and performance test

The original stove prototype, which was initially obtained from Bandung, Indonesia, was intended only for jatropha seed burning. But after testing it, the stove has showed large amount of disturbing smoke, excessive flame loss and in-convenient handling and flame controlling system. Thus, modification is made in order to solve the problems and to diversify its fuel feed stocks to jatropha and castor seeds and their pressed cake and some chunky wood and grass fuels. During modification of the stove, the air opening adjustment is modified to allow various ranges of flames differences while it opened and closed from its bottom. Since the energy density of the pressed cake and the chunky fuels are lower than the oil seeds, therefore, the cylinder and chimney heights were enlarged. In addition, as the compactness of the cake and husks also needs more air (oxygen), therefore opening sizes were considered during the modification. The stove was evaluated for the following four parameters: Thermal efficiency, Charcoal making efficiency, fuel burning rate and working time. For the purposes of the measurements, the following empirical formulas obtained from Shell Foundation (2008), as in [13], were utilized as follows.

- The specific fuel consumption for each biomass fuel will be determined.

$$\mathrm{SFC} = \frac{M}{Vw} \quad (2.1)$$

Where; M = mass of biomass fuel used (g) and Vw = volume of liquid/water evaporated (cm3).

- The burning rate for each biomass fuel in the gasifier stove will be determined.

$$\mathrm{Br} = \frac{M}{t} \quad (2.2)$$

Where; Br = burning rate (g/min), M = mass of biomass fuel (g) and t= time taken (minutes).

- The proportion of charcoal produced will be determined from the mass of biomass fuel used and mass of charcoal produced.

$$\mathrm{Cp} = \frac{M-Mc}{M} * 100 \quad (2.3)$$

Where; Cp = proportion of charcoal (%), M = mass of biomass fuel (g), Mc = mass of charcoal (g)

- The Thermal energy efficiency for each biomass fuel was also determined.

$$\mathrm{TE}=(\mathrm{Qu})/\mathrm{Qa} \quad (2.4)$$

Where: Qa = W * C, where Qa is the heat generated by the wood (dry weight), W = weight of the wood burnt during the trial, C = the calorific content of the wood estimated as 17.39 kJ/g.

$$Qu = (Wi - Wf) * Cv + (Tf - Ti) * Wf * Ce, \quad (2.5)$$

Where: Qu = heat utilized (kJ), Wi = initial weight of water (g), Wf = final weight of water (g), Cv = water vaporization heat (2.253 kJ/g), Ti = initial water temperature (^{O}C), Tf = final water temperature ((^{O}C), Ce = water specific heat (0.0042 kJ/g/(^{O}C)).

2.4 Chemical and Physical Property Tests of Jatropha Oil

After pressing the jatropha oil, it was filtered by using cotton garment and very fine meshed plastic funnel before tests. A sample of pure jatropha oil and three samples of blends (5%, 10% and 20% Jtropha oil with diesel) were subjected to selected parameters of chemical and physical characterization test at standard fuel test laboratory of Ethiopian Petroleum supply Enterprise, by using American Society for Testing and Materials (ASTM) standard.

(a)

(b) (c)

Fig2.1. The hydraulic press (a), pressed oil (b) and cooking stove (c).

3 RESULTS and DISCUSSION

3.1 Hydraulic Presses Performance Test

Table3.1.1. Shows that the results of the three types of press in working with the four types of jatropha seeds. Among the tested presses, press No.3 shows better results followed by press No.1 (except in some results) in terms of output in liters per hour, liters per 15kg seed extraction, extraction rate and extraction efficiency. However, the three presses take similar working hours for their outputs. In terms of the seed types used and the presses interaction, all the presses performed well in pressing the seed obtained from the Ziway. The seed from the Ziway area also yield better output oil per 15kg seed and the rest seeds from west Ethiopia (Sire, Bako, and Arjo) results in almost similar out puts in liter per 15kg out puts. But, in general, from the results presented, it is obvious that there is no significant difference between the results obtained in terms of presses performances and the oil output of seeds. In Table 3.1.2, the results of the three types of press in working with the three types of Castor bean seeds. Here, press No.3 also shows better results in the considered parameters. However, more less differences are resulted in the outputs of the devices per hour and extraction rate. The oil yield of the used seed types shows similar outputs, with the chocolate color seed (No.1) 3.8litre/15kg seed when pressed by press No.3.

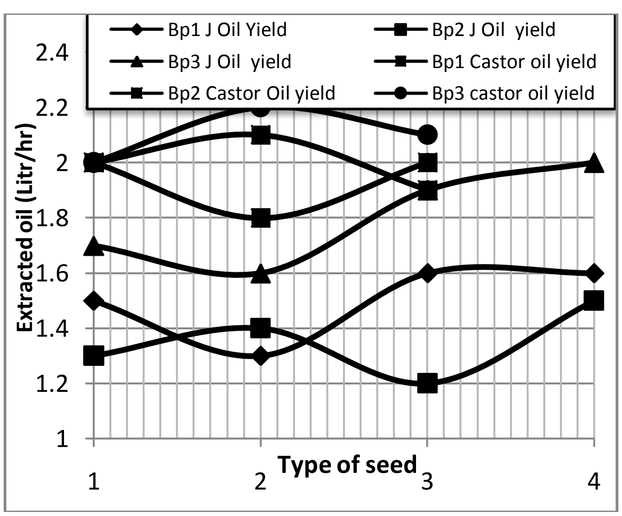
Table3.1.1. Results of the jatropha seed oil extraction with the Bako presses.

Type of Bako Presses	Jatropha Seed	liters/hr	liters/15kg	Hours /15kg	Extraction rate (%)	Efficiency (%)
Bp1 or P1	Arjo (1)	1.5	2.9	2.1	17.6	46.3
	Bako (2)	1.3	2.9	2.4	17.6	46.3
	Sire (3)	1.6	3	2	18.2	47.9
	Ziway (4)	1.6	3.1	2.3	18.8	49.5
Bp2 or P12	Arjo (1)	1.3	2.8	2.4	17.0	44.7
	Bako (2)	1.4	2.8	2.2	17.0	44.7
	Sire (3)	1.2	2.9	2.6	17.6	46.3
	Ziway (4)	1.5	3	2.1	18.2	47.9
Bp3 or P3	Arjo (1)	1.7	3.2	2	19.4	51.1
	Bako (2)	1.6	3	2.3	18.2	47.9
	Sire (3)	1.9	3.2	2	19.4	51.1
	Ziway (4)	2	3.4	2.4	20.6	54.3

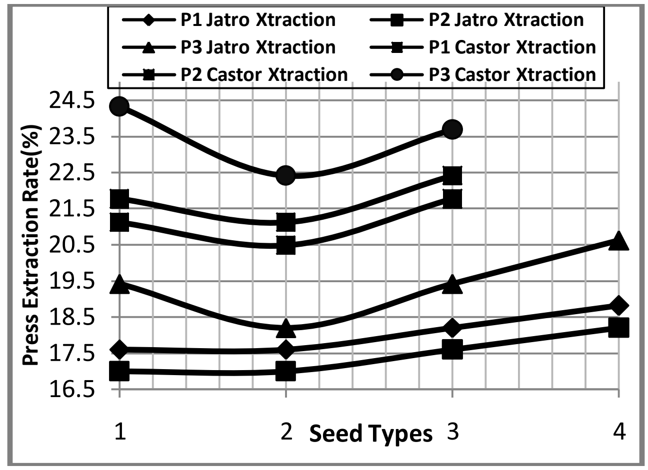
Table3.1.2. Results of the castor seed oil extraction with the Bako presses.

Type of Bako Presses	Castor bean	liters/hr	liters/15kg	Hours/15kg	Extraction rate (%)	Efficiency (%)
Bp1 or P1	1	2	3.4	2	21.8	43.5
	2	2.1	3.3	2.3	21.1	42.2
	3	1.9	3.5	2.3	22.4	44.8
Bp2 or P2	1	2	3.3	2.2	21.1	42.2
	2	1.8	3.2	1.9	20.5	41.0
	3	2	3.4	2.5	21.8	43.5
Bp3 or P3	1	2	3.8	2.3	24.3	48.6
	2	2.2	3.5	2.1	22.4	44.8
	3	2.1	3.7	2.3	23.7	47.4

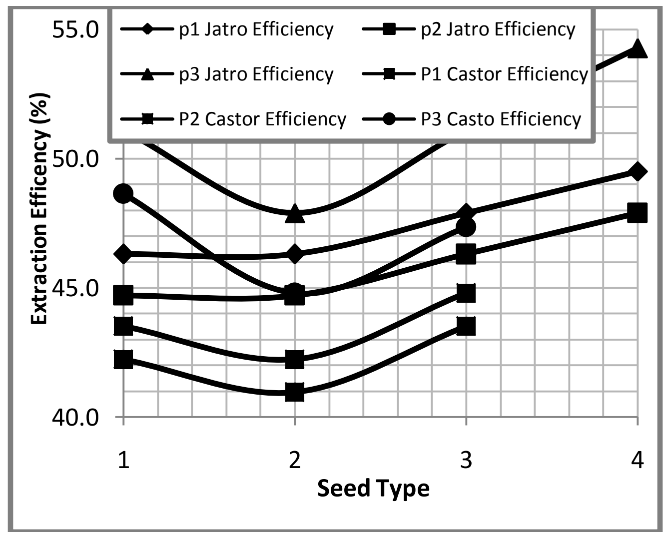
In both seed varieties tests (Jatropha and castor seed), press No.3 shows superior to the other in all aspects. But an especially marked difference can be observed for the efficiency, which for prees3 from a minimum of 44.8% which is equal to the two presses maximum efficiencies and its maximum efficiency is 54.3% in jatropha seed pressing and in castor bean seeds pressing, with maximum 48.6 followed by press No1 maximum 44.8% which is equal to minimum efficiency of the press No.3. The press has been concluded with the capacity of about 1.2 - 2 liters oil per hour. The time taken by the presses are ranges between 2 hours to 2.6 hours, which is 2-2.4 hours for the press No.3 and this can be 4-5 minutes to press 450 grams seed in Single batch press in the latter device.



(a)



(b)



(c)

Fig3.1. Variation in the Presses performances: extraction capacity (a), extraction rate (b) and extraction efficiency (c) with jatropha and castor seeds.

However, probably the more important indicators of the quality of machines such as the extraction rate was higher in the second test and the efficiency are definitely higher in the first test. On average, the extraction rate in the castor seed test is almost 4% higher than in the jatropha test, and in case of efficiency the difference is also similar 4% for the reverse condition. These results are also shown in figure 3.1. The numbers of reports on the mechanical analysis of the hydraulic jack powered press system are limited, but similar results are reported by other works. 0.98 L volume of oil out of 3.95 kg of Seed in 1 hour in conventional hand operated expeller [6]. The same author also used a ¾ HP motor expeller and reported about 4 liter of oil for every 12 to 16 kilograms of jatropha seeds in an hour. By a simple mechanical screw-press 41.8 kg of seeds pressed and yield 11.71 kg *Jatropha* oil and 30.09 kg cake [9]. a ram press used by [7] and reported 6.88 kg of oil per 32 kg seeds, representing about 21.5% of crude oil by weight per kg of the dry weight of the *Jatropha* seed. But, powered mechanical presses usually resulted in 30 to 38% jatroph yield [8].

3.2 Cooking Stove Performance Test

As it can be seen from table 3.2, the eucalyptus wood had the lower starting time of 7.0 minutes and jatropha press cake had the highest starting time of 16.5 minutes. There was variation in the operation time of the same mass biomass fuels in the stove: castor seeds had the highest operation time o f 83 minutes and wood had the lowest operation time of 23 minutes. After full starting of the flame, the jatropha seed had the lowest average time (10minutes) to boil of 10litre water and the cake from the jatropha had also 21.5 minutes higher time to boil the water. This result shows that jatropha seeds have highest burning energy per unit time in the stove after starting and the lower performances of the jatropha press cake, which might be due to its extreme dryness due to pressing and compaction. Wood had the highest specific fuel consumption (SFC) of 1.43 g/cm^3 and jatropha seeds had the lowest SFC of 0.98 g/cm3. Wood had the higher average burning rate of 21.74 g/min and castor seeds had the lowest burning rate of 7.17 g/min. Jatropha seeds produced the largest proportion of charcoal of 36% from mass of the seed and its cake also produced the lower charcoal proportion of 21%. Thermal Energy efficiency has an effect on the performance of the biomass fuels in the stove during a thermal application. It shows how the stove can save energy from the different biomass fuels when used in it.

Table 3.2 Summary of average results of cooking stove trials with the selected fuels

Parameter	Test				
	Jatropha seed	**Castor seed**	**Jatropha cake**	**Castor cake**	**Wood**
Starting time (min)	12	14.5	16.5	15.0	7.0
Time to boil 10 Liter water (min)	10	16.7	21.5	18.5	13.5
Total burn time (500gm fuel) (min)	69.7	83	47.7	51	23
Specific fuel Consume (gm/cm3)	0.98	0.99	1.05	1.04	1.43
Burning Rate (gm/min)	7.17	6.02	10.48	9.80	21.74
Charcoal Proportion (%)	36	32.2	21	22	26.2
Thermal efficiency (%)	15.7	15.4	12.1	14.9	16.5

Here, the thermal efficiency of the stove lied between 12.1% in jatropha cake and 16.5% in using wood. Except, the lower efficiency of using the jatropha cake, the stove has almost similar efficiencies in the used bio-fuels. Although, the biomasses and stoves types are different than those used in the current study (except the wood biomass), some similar results have been also reported in previous works; using plancha biomass, [10] reported 12% overall thermal efficiency of the plancha stove. The efficiency of gravity stove with karanj is 11.81% and conventional stove is 5.65% [11]. Jatropha fruit coats and saw dust in a saw dust stove and reported 24% thermal efficiency [12]. Thus, the study concluded that, the results of the current study were in line and/or better than the results of most previous work in the literature review.

3.3 Physical and Chemical Test of Jatropha Oil

The test results of the jatropha oil and its blends in relative to the AGO (diesel) fuel are provided alongside the AGO limit of diesel fuel specification of the enterprise in Table 3.3.

Table 3.3 Comparison of blends samples and pure jatropha oil with diesel (AGO) properties

Property	Test method ASTM	Limit (AGO)	Test Result				
			AGO	95% AGO 5% Jatropha oil	90% AGO 10% Jatropha oil	80% AGO 20% Jatropha oil	Jatropha Oil
Density @ 15 ^{0}C gm/ml	D1298	Report	0.848	0.852	0.855	0.862	0.9176
Density @ 20 ^{0}C gm/ml	D1298	Report	0.844	0.849	0.852	0.859	0.9143
FBP, ^{0}C		Max. 390	379	375.5	380.5	377.5	353.0
Flash pt. (PMCC), ^{0}C	D93	Min. 52	65	65	65	67	214
Cloud point	D2500	Max. 5 ^{0}c	-2	0	-1	0	-5
Kinemat viscosity	D445	Min. 1.9 Max. 4.1	3.29	3.71	4.07	5.31	36.92
Water and sediment	D2709	Max. 0.05		∠0.01	∠0.01	∠0.01	∠0.01
Total acidity mg KOH/g	D974	Report		0.088	0.183	0.342	1.402
Ash content	D482	Max. 0.01		0.0008	0	0	0.0095

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The blends (5%, 10% and 20 %Jatropha oil) viscosities were: 3.71, 4.01, & 5.31 cSt respectively, while that of the pure oil is 36.92. Reduction of J20 is 29% (very close to ASTM limit). Flash points of blends of 5% and 10% Jatropha oil are similar to that of the diesel but that of the 20% Jatropha oil is also very closer to them at 67 when compared to the pure jatropha oil of 214. Water and sediments of blends and of the oil are ∠0.01, lower than the limit of Max. 0.05. Ash contents of the blends are also very low than the limit. Here, the properties of the AGO, the results of the pure jatropha oil properties were higher than the AGO limit. But that of the blends are comparable to the AGO in both temperatures of 15 ^{0}C and 20 ^{0}C. Similar results were also reported by [4] and [9] for *Jatropha* oil and their blends in different ratios.

3.4 Additional Observations

In addition to the development of the pressing machine and stove for seeds, a simple design of kerosene wick stove type and a lamp were also developed for crude oil utilization. However, although this attempt produces promising results in the demonstration of the jatropha/caster bean seed oil system, but their smoke level has been identified as a drawback in their performance tests and the devices are still under improvements. Soap from Jatropha crude oil was made and promoted the jatropha system for users successfully. Since high viscosity of the plant oils is considered to be the major constraint in using them in diesel engines, thus, after the laboratory tests of the blends (Table3.3), the blending of the plant oil with diesel were used in a diesel engine and resulted in similar Engine thermal efficiency to the fossil diesel.

4 Promotional Activities of the Devices

Since the final goal of the current study was promotion of the tested and promised device for the users, therefore, an effective promotion works have been conducted in different parts of Ethiopia, by involving variety of participants: Farmers, woreda Agricultural Development offices, ministry of Water and energy, NGOs, women's groups, Small and Micro Enterprises, Ministry of Science and Technology and some Universities. The mode of promotion includes: trainings of peoples from all regions in the center and in different locations. Accordingly, prototypes have been passed on to the users through the selling mechanisms to 7 regional state of the country in the last three years, and it is estimated that, more than 10, 000 users have been reached in the promotion activities done by different stakeholders (GOs and NGOs).

5 CONCLUSION

Based on the analysis of the three manually operated hydraulic press machines, one of the centers versions, the press with the vertical position arrangement of the crucial parts (piston, jack, and cage) had the best performance. Its operation is made simple which is mainly done by standing and pressing down the hydraulic jack's lever by a hand or by a foot down and up at a built spring mechanism. The capacity of the press is about 1.2 - 2 liters per hour. On the other hand, since the current press machine is a batch system, so that continues and higher extraction rate improvements should be the direction in future work. The results from the jatropha and castor seeds were not significantly different from Eucalyptus wood basing on; starting time, operation time, time to boil 10 liters of water, specific fuel consumption, burning rate, charcoal proportion and thermal energy efficiency. The jatropha and castor cakes had lower performances compared to the rest of the selected biomass fuels which are important at increasing the biomass energy efficiency. They were faced with a problem of higher starting time and still capable of being used in the stove. The energy efficiencies of the biomass fuels in the developed stove lied between 12.1% and 16.5%. In addition, the stove test shows no significant differences of flame height and fuel consumption rate but with very reduced amount of smoke and continues blue red flame, especially in jatropha and caster bean seeds and the wood. In the laboratory test results of the jatropha oil, diesel (AGO) and blends, the properties of the pure jatropha oil properties were higher than the AGO limit. But that of the blends are almost comparable to the diesel. Thus, it was concluded that, this work achieved most of its objectives to develop appropriate devices, create an interest and awareness of the jatropha/ castor production and utilization, which may help improving the development in the rural areas of the country.

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