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Determination of Technical and Functional Properties of The Homemade Olive Oil Extraction Plant

Yousef SAEIDI LIGHVAN[1], R. Cengiz AKDENIZ[2]

[1] PhD Student in Ege University, Graduate School of Natural and Applied Sciences, Department of Agricultural Machinery, Bornova-İzmir/TÜRKİYE

[2] Ege University Faculty of Agriculture , Department of Agricultural Machinery, Bornova-İzmir/TÜRKİYE

[1] yusuf.saeidi@gmail.com
[2] cengiz@ebiltem.ege.edu.tr

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Abstract: This study has been conducted for the purpose of evaluating technical qualities of homemade olive oil production line. Memecik type of olive is used as the main material in this study. Energetic parameters of units and the factors affecting the performance of the plant were investigated. The specific energy consumption (SEC) values were 68.33×10^{-3} and 8.857×10^{-3} kWh/kg in terms of gross (EEC_g) and net (EEC_n) electric energy consumption, respectively. Also, the ratio of EEC_n to EEC_g which was 11.14 % defined as the percentage of productive energy (PE). The motors belonging to olive conveyor in defoliation-washing system (DWS) and decanter and pomace discharge pump in olive oil extraction system (OOES) were inefficient according to power utilization (%) values. Accumulation of product on the internal surface of the malaxer caused to maximum non-repeatable product loss (NRPL) of 3.07 %. However, in terms of repeatable product loss (RPL) 0.38 % of the olives and 2.74 % of the oil was wasted through the process. In addition, olive mill waste water (OMWW), olive oil extraction efficiency and average particle size of crushed olive stones were stated as 1.51 m^3, 89.57 % and 3.249 mm respectively. Process temperature, which was 27^oC max., degree of free acid, the number of peroxide and UV absorption amount place the produced olive oil into the category of 'Virgin Olive Oil' or 'First Cold Pressed Olive Oil' according to both national and international standards.
Keywords: Olive oil quality, olive oil extraction system, specific energy consumption, electric energy consumption

INTRODUCTION

Cares about a healthy life and increasing request, has led to the formation of new markets in olive oil production and its growth in the world. According to the average values between years of 1990/1999 and 2000/2009; there were significant increases in olive oil production, exportation and consumption of the world as 29.82, 72.02 and 31.42 % respectively (FAO, 2013). In the case of Turkey, for the same period, production, exports and consumption shows increase by 37.67, 47.99 and 31.50 %, respectively.

Traditional press and modern extraction systems have improved for obtaining olive oil where 2-phase and 3-phase centrifuge systems as continue also modern extraction systems have had higher efficiency and found suitable for automation compared with other systems.

From about two decades ago, 2-phase centrifuge system got importance as an ecological process because of its higher oil extraction efficiency, less energy and water consumption and less waste water production subsequently (Giannoutsou et al., 2004). Tomati and Galli (1992) revealed the waste water production range of 1.2- 1.8 m^3/ton for centrifugal systems as the negative environmental impact of the process. In addition, during the *Improlive project (FAIR CT96-1420*, 2000*)* specific energy consumption (SEC) range of 0.090-0.117 kWh/kg for 3-phase and less than 0.090 kWh/kg for 2-phase systems were reported.

Three phase electric motors have been used in centrifuge systems as power source of all unites in which olive crusher, malaxer and especially decanter defined as the main electric energy consumption unites (Cini et al., 2008; Altieri et al., 2010). Generally, such motors aren't applied effectively which has led to energy loss (Hurst, 2007; Da Costa Bortoni, 2009). Therefore, controlling and evaluating energy consumption during process defined as solution key by researchers (Altieri et al., 2010; Saidur, 2010).

In the present paper, the performance of a homemade olive oil extraction system was evaluated. For this purpose, defoliation-washing efficiency, product loss, olive mill waste water (OMWW) as an environmental problem, temperature changes during the process and also several characteristics of olive fruits and particle size analysis of crushed olive stones which affect the olive oil quality and extraction efficiency was investigated. In addition, electric energy parameters were measured by developed Electric Energy Monitoring System (EEMS).

MATERIALS and METHODS

Memecik variety of olive harvested (80 kg) at the end of the December from Torbali County of Izmir (Turkey) by a pneumatic harvesting machine was used as the main material. The study was carried out on the *KOCAMAZ Machine Industry olive oil extraction machines R&D laboratory* and quality analysis was accomplished in *Verde chemistry laboratories* where both of them have located in Torbali.

Investigated plant consists of defoliation-washing system (DWS) and olive oil extraction system (OOES) with 200 and 60-80 kg/h work capacity, respectively. As shown in Fig 1, the process includes following main steps: defoliation-washing, crushing at 1000 rpm in the hammer mill with the screen size of 6mm, vertical kneading without heating effect and centrifugation in 2-phase decanter at 3600 rpm.

Fruit Characteristics

Maturity index (M.I.) of olives calculated investigating skin-flesh color change of 100 olives samples which selected randomly from 1 kg with regard to the method published by the International Olive Council (IOC, 1984). M.I. values are defined from 0 (deep green skin) to 7 (black skin and all the flesh purple to the stone).

Moisture content detected by drying 10-20 g crushed olive samples (with kernel) in a 105 ^{o}C oven. Also, the same method was used for olive pomace moisture content determination (TS 1632 EN ISO 665, 2001).

Oil content determination of olives and olive pomace samples was performed applying Soxhlet apparatus (TS EN ISO 659, 2010).

Fruit hardness (kg) of randomly selected 100 olive samples measured by using the FHR-1 fruit hardness tester (Bal and Çelik, 2008).

Fresh/Stone ratio calculated by weighing fresh and stone parts of the fruit separately using Sartorius L610 precise balance (Kutlu and Şen, 2011).

Arithmetic mean diameter (D_a), geometric mean diameter (D_g) and Sphericity (φ) of the olive fruits were calculated from the geometrical dimensions as below (Mohsenin, 1986):

$$D_a=\frac{(L+W+T)}{3}\ (mm) \quad (1)$$

$$D_g=(L.W.T)^{1/3}\ (mm) \quad (2)$$

$$\varphi=\frac{(L.W.T)^{1/3}}{L}\times 100\ (\%) \quad (3)$$

Where *L, W* and *T* are *length, width,* and *thickness* of the olive fruit, respectively.

Performance Evaluation

A method was developed for determination of defoliation-washing efficiency in the DWS:

$$DWE=\frac{X_n-Y_n}{X_n}\times 100\ (\%) \quad n=1,2,3 \quad (4)$$

Where, DWE is defoliation-washing efficiency and X_n, Y_n are the numbers of olive leaves (n=1), branches (n=2) and leafy branches (n=3) before and after defoliation-washing process, respectively.

Product losses detected as non-repeatable (NRPL) and repeatable (RPL) product losses as much as possible without damaging the plant. For NRPL, remained material in each step of the process excepting the olive paste transfer pump and the decanter was weighed. These are fixed losses which happen at the start of the each working process and don't increase or repeat through the process. On the other hand, the oil content of the olive pomace as unextracted oil after decantation also amount of wasted or not transferred safe olives through the defoliation-washing process defined as RPL which repeat continuously.

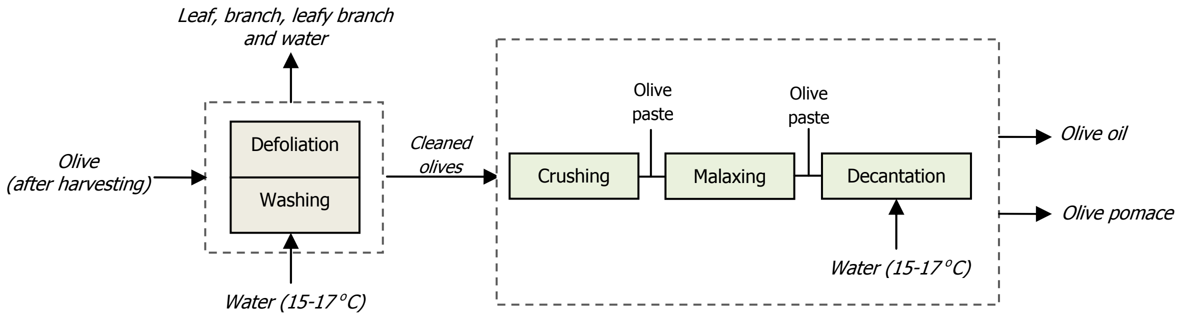

Figure 1. Flow diagram of the process

OMWW (m^3/ton) was evaluated considering water content of olive pomace and water consumed in DWS which measured using a water meter (Tomati and Galli 1992).

The ratio of the extracted olive oil to the oil content of the olives calculated as olive oil extraction efficiency (*η*) (Catalano et al., 2003).

$$\eta = \frac{\text{Extracted olive oil (kg)}}{\text{Oil content of the olives (kg)}} \times 100 \ (\%) \qquad (5)$$

The olive pomace sample was diluted in water for separating olive stone particles from other parts. Subsequently, particle size analysis of the separated stone particles was accomplished according to ASABE (2006) standard.

Free fatty acid (% oleic) content, peroxide value (meq O_2/kg) and UV (ultraviolet) spectrophotometric indices (k_{232}, k_{270} and ΔK) were analyzed as quality factors of the extracted olive oil according to standard methods (TS 342, 2003). Also, the temperature changes for its importance in olive oil classification controlled during extraction process applying Ram DT 8835 infrared thermometer.

Electric Energy Monitoring System (EEMS)

Studied plant is consisted of six 3-phase electrical motors in which hammer mill and decanter are powered by a common 3 kW motor exceptionally. So, EEMS was developed in order to measure and record active power (kW) and energy consumption (kWh) of the motors in two loaded/gross (EEC_g) and unloaded (EEC_u) working states.

This system is composed of CASE Pa 300 energy analyzers, three current transformers (CT) for each analyzer and RS485/RS232 data converting device which transfers converted data to the computer continuously (Fig. 2).

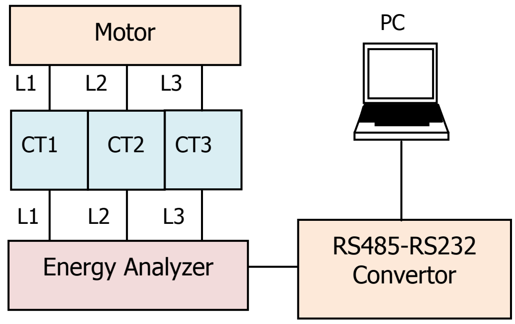

Figure 2. Flow diagram of the EEMS

Productive Energy (PE) and Specific Energy Consumption values in terms of EEC_g (SEC_g) and EEC_n (SEC_n) calculated as follows:

$$PE = \frac{EEC_n}{EEC_g} \times 100 \ (\%) \qquad (6)$$

$$SEC_g = \frac{(EEC_g)}{W} \ \left(\frac{kWh}{kg}\right) \qquad (7)$$

$$SEC_n = \frac{(EEC_n)}{W} \ \left(\frac{kWh}{kg}\right) \qquad (8)$$

Where, EEC_n (kWh) as the net value of electric energy consumption is the difference of EEC_g (kWh) and EEC_u (kWh) and W (kg) is the weight of end product in each process step considering product loss.

RESULTS and DISCUSSION

Different characteristics of the olive fruits used in the experiments, obtained as shown in Table 1. These properties change with such fruit variety, climate condition and harvesting time factors (El- Soaly, 2008;

Nergiz and Ergönül, 2008; Kutlu and Şen, 2011; Valente, et al., 2013).

Table 1. Various characteristics of olive fruit

Fruit characteristics	Values
Storing duration (day)	3
Maturity index	4.90
Moisture content (%) (wet basis)	47.83
Oil content (%)	16.21
Hardness (kg)	0.16
Fresh/stone	3.12
Arithmetic mean diameter (mm)	16.20
Geometric mean diameter (mm)	15.84
Sphericity (%)	74.79

The DWE values as the performance factor of DWS showed that 64.53 % of leaves, 85.71 % of branches and 62.5 % of leafy branches could be separated from olives. Feeding flow rate, fan power and slope angle of discharge channel of olive leaves, branches and leafy branches recognized as the factors affected the DWE value.

As shown in Table 2, technical design defects in junctions such as *washing tank-olive conveyor* and *hammer mill feeder-hammer mill* caused to accumulation of olive fruits in junction point and NRPL. Also, olive paste accumulated between *agitator blades-internal surface of the malaxer tank* and *screen- shield of hammer mill* due to the same reason. Furthermore, the olives were taken out by the fan and 2.74 % oil content of olive pomace identified as not extracted oil and RPL.

Table 2. Product loss determination

		Final production (kg)	NRPL (%)	RPL (%)
DWS	Fan	79.7	-	0.38
	Olive conveyor	78.8	1.14	-
OOES	Hammer mill feeder pump	79.8	0.25	-
	Hammer mill	78.85	1.21	-
	Malaxer	76.5	3.07	-
	Oil content of olive pomace	-	-	2.74

Total water consumption for the extracting line was 1.16 m^3/ton of production (olive-olive paste) so that 59 % was for decanter and 41 % for DWS. In addition, the total amount of 1.51 m^3 waste water per each ton of olive found to be an acceptable value based on the range of 1.2- 1.8 m^3/ton waste water generation in centrifugal extraction systems which mentioned in literature.

Olive oil extraction efficiency was 89.57 % whereas moisture content, oil content and average solid particle size of olive pomace obtained as 64.27 %, 2.74 % and 3.249 mm respectively.

As revealed in Table 3, extracted olive oil has taken place in Extra *Virgin Olive Oil* class (TS 341, 2004). On the other hand, the temperature of product during all process didn't exceed the limit of 27^{o}C. Therefore, obtained oil classified as *first cold pressed olive oil* (European Commission Regulation (EEC) No. 1019/2002).

Table 3. Extracted olive oil characteristics

Characteristics	Values
Free fatty acid (% oleic)	0.47
Peroxide value (meq O_2/kg)	2.9
K_{232}	1.55
K_{270}	0.11
ΔK	-0.0035

As seen from Figure 3 and Figure 4, power usage changes during all process was analyzed. Considering power utilization (%) values in Table 4, the olive conveyor, decanter and especially pomace discharge pump motors found ineffectual because of over-sizing problem.

Results showed that the biggest part of electric energy consumption has been used as EEC_u concerning PE values.

In terms of EEC_g, whereas 99.22% of the SEC_g, which was 68.33×10^{-3} kWh/kg, belonged to OOES and 0.78% of it belonged to DWS.

Also, detected SECg value with 68.33×10^{-3} kWh/kg was less than 0.090 kWh/kg which published in the literature for 2-phase olive oil extraction systems.

As for in terms of EEC_n, whereas 98.91% of the SEC_n which was 8.857×10^{-3} kWh/kg in total, belonged to OOES and 1.09 % of it belonged to DWS.

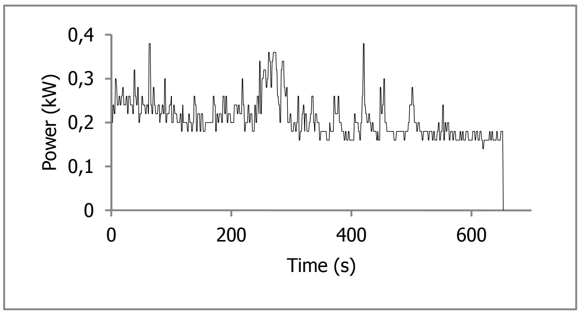

Figure 3. Power consumption changes in olive conveyor unit which belongs to DWS

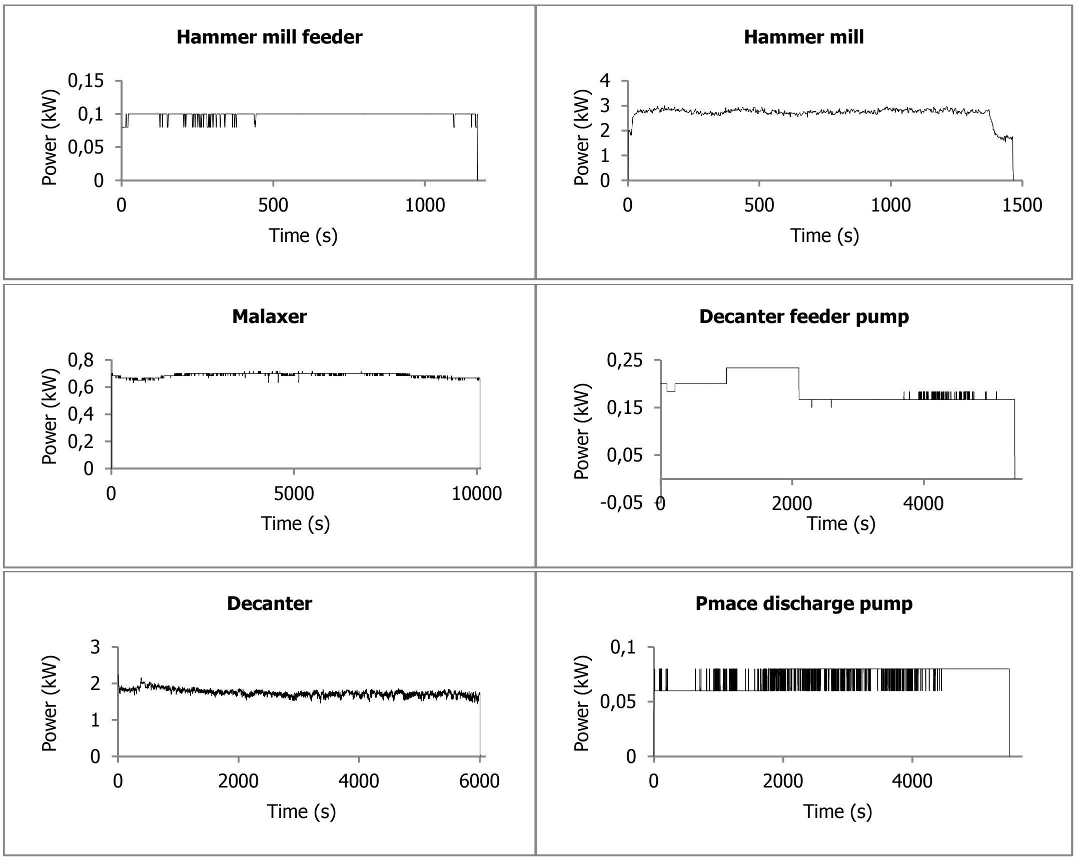

Figure 4. Power consumption changes in all units belonging to OOES

Table 4. Power utilization and energetic parameters of the process

	Motor	Installed power (kW)	Power utilization (%)	EEC_u	EEC_g	PE (%)	SEC_g	SEC_n
							(kWh/kg) $\times 10^{-3}$	
DWS	Olive conveyor	0.37	56.76	0.0344	0.042	18.10	0.53	0.097
OOES	Hammer mill feeder pump	0.12	82.50	0.0346	0.038	8.95	0.48	0.04
	Hammer mill	3.00	91.50	0.774	1.241	37.63	15.74	5.92
	Malaxer	0.75	90.67	1.808	1.952	7.38	25.52	1.88
	Decanter feeder pump	0.18	100	0.243	0.273	10.99	2.13	0.23
	Decanter	3.00	58.33	2.890	2.940	1.70	22.88	0.39
	Pomace discharge pump	0.18	39.56	0.089	0.123	27.64	1.05	0.29
	Total	4.60	-	5.873	6.609	11.14	68.33	8.857

CONCLUSIONS

Several characteristics of the olives which affect the olive oil quality, extraction efficiency and energy used for the extraction process were detected. The performance evaluation of DWS indicated weak values of DWE in case of leave and leafy branches because of technical defects which caused to the NRPL and RPL at the same time.

The results displayed that gross (total) value of specific electric energy consumption and OMWW were in acceptable level regarding the literature. On the other hand, the necessity of using well suited motors for olive conveyor and pomace discharge pump units also considering a mechanism to perform independence operation of hammer mill and decanter units in order to prevent energy loss was revealed.

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