

ENVIRONMENTAL POLLUTION RESULTING FROM OLIVE OIL PRODUCTION

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Abstract

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The level of environmental impact of olive oil production in Palestine is evaluated. The evaluation method is based on conducting a local survey; after designing a questionnaire covering the basic aspects that includes oil production yield, water consumptions in olive washing and in oil recovery, wastewater generation relative to olive processed and oil generated, and solid waste generation. The data were collected from 92 local olive oil mills, which were analyzed and organized according to the investigated parameters, and categorized according to local selected areas in the West Bank such as Hebron (South), Nablus (middle) and Jenine (North). The results reveal local variations in most of the investigated parameters due to variations in the type of olive produced. The south olives are found to contain larger solid content than those in the north, resulting in lower oil yield and higher solid generation per ton of olive produced.

Key words: olives, olive oil, oil yield, solid waste, water consumption, wastewater

Introduction

Annually, approximately 1.8×10^6 tons of olive oil is produced worldwide, with a majority being produced in the Mediterranean basin (Paredson, 1999), (Tamburino, 1999). Treatability of olive mill wastewater has been investigating using respirometric method (Kiril, 2008). In Palestine, olive and olive oil production is an important source of income for a considerable sector of farmers. From Agricultural

prospective, olives and their oil have major contributions in the Palestinian economy. Olive farms covers almost half of the cultivated area in The West Bank, and oil production contributes by around 28.7% of the agriculture domestic income, there are about 246 olive mills in The West Bank (Palestinian international information, 2005). The operations of these mills are spilt between modern and traditional models. Naturally, olive mills are generally situated close to olive orchards.

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The Palestinian Nation Information Center published the overall statistical information about the number of mills, and total amounts of olive and olive oil produced in The West Bank and Gaza between the years 1998 to 2002. No recent data beyond 2002 are available which shows that there is a slight change in the overall percentage oil yield from year to year.

Generally extraction of oil is carried out either by continuous or discontinuous processes, and both methods generate wastewater, which consists of the water contained in olive fruit, the added water required for washing the fruit, and for the centrifugation process. With continuous process, the average amount of olive mill wastewater (OMW) is 1.2-1.8 m³/ton of olives, while with discontinuous process; it is only 0.4 - 0.5 m³/ton of olives (Tomati, 1992).

The color of wastewater produced in both methods is usually black or reddish black due to the presence of phenolic compounds. The typical composition of OMW includes water (83%), organic compounds (15%), and inorganic chemicals (about 2%). The organic load in OMW is considered one of the highest of all concentrated effluents, being 100-150 times higher than the organic load of domestic wastewater. In general, OMW produced in discontinuous mills contains higher organic load than those generated in continuous mills. OMW is acidic, and contains high concentration of total suspended solids (TSS), total dissolved solids (TDS), phenols, and other organic matter. The organic content is characterized by high levels of chemical oxygen demand (COD), biochemical oxygen demand (BOD), and very high concentration of fat, oil, and grease (FOG) (Jordanian Ministry of Agriculture, 1998). No standard for OMW discharge disposal is currently imposed in Palestine, but the Jordanian standards are adopted (Table 1) (Jordanian ministry of agriculture 1998), (Jordanian standard report no.202, 1991) and (water authority law no. 18, 1988). The BOD and COD maximum concentrations in OMW reach 100,000 and 220,000 mg/L, respectively. The OMW consist toxic organic materials such as sugars, tannins, polyphenols, polyalcohols, pectins, proteins, and lipids (Kiritsakis, 1991). Ecological stabilization and detoxi-

fication of their effects are expensive and ineffective (Borja, 1992) and (Martin, 1995).

Currently, there is no appropriate method applied for treating OMW in Palestine; it is usually disposed of in sewage systems and/or cesspools in addition to being discharged into water streams and valleys in the region. Due to the presence of high load of toxic organic compounds, the improper discharge of OMW causes the disruption of biological activities in domestic wastewater ponds. This creates a strong and unpleasant odor due to aerobic digestion in open air systems, and poses a threat to surface and groundwater (Hamdi, 1992) and (Sorlini, 1986). The disposal of OMW causes serious environmental problems during the olive harvest season. In addition to wastewater generation, a large amount of solid waste is generated. This emphasizes the environmental concerns associated with olive oil production and highlights the need for this study.

This paper evaluates the level of environmental impact of olive oil production in Palestine through conducting a survey in the West Bank. A questionnaire covering the basic aspects of the paper was designed, the investigated parameters include: yield of oil from olives, water consumptions in olive washing and in oil production, wastewater generation, solid waste generation.

Material and Method

During survey activity, the West Bank was under Military closer. The number of olive mills operating in The West Bank and Gaza during the season (2001-2002) was about 194 mills, and some of them were closed due to political situation and there were about 10 mills in Gaza which could not be reached. Thus, 92 olive mills through out The West Bank could be reached and included in this survey.

The obtained data were analyzed and organized according to the investigated parameters and then categorized according to local areas in the West Bank; Hebron (south), Nablus (middle) and Jenine (North).

Experimental work was performed for obtaining typical characteristics of OMW in Palestine, by ob-

Table 1

Characteristics of OMW in Jordan and comparison with Jordanian standards and regulations for OMW [6-8]

Parameter	Unit	OMW Characteristics Min.-Max.	Maximum Allowable Limit- Jordanian Standards		
			Disposal to wades and rivers	Reuse for irrigation	Discharge to sanitary systems
pH	SU	5.48-5.91	6.8-9.0	6.5-8.4	5.5-9.5
COD	mg/L	78536-160096	150	undetermined	2100
BOD ₅	mg/L	23248-63271	50	undetermined	800
TSS	mg/L	14207-46188	50	100	1100
TDS	mg/L	16984-80355	3000	2000	
FOG	mg/L	2008-13118	5	5	50
Phenol	mg/L	1739-4432	0.002	0.002	10

taining samples from a representative olive mill at three intervals of the harvest season (beginning, middle and end of season). The major characteristic parameters of the wastewater are determined using the standard tests. These include pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD₅), total suspended solids (TSS), total dissolved solids (TDS), concentration of fat, oil, and grease (FOG), phenols, electric conductivity (EC) total Phosphorus (T-P) and total Kejnjal nitrogen (Tkj-N).

Results and Discussion

Analysis of the overall data published by the Palestinian National Information Center provides (Figure 1) oil yield (defined as percentage of amount of oil produced per amount of olive processed), which compares the amount of olives and olive oil produced in various parts of The West Bank and the overall yield in 2002? Jenine produced the largest amounts of olives and olive oil. There are some variations in the overall yield between the locations. The estimated average overall yield was 22.3%. Obviously, olives and olive oil production is more popular in the north areas, and the oil yield is higher than that in the south

The obtained fitting R² values are almost above 0.99. The oil yield (%Oil/Olive) has an average value of 23.7%, which is in accordance with the previous

reports, with a difference of 1.4%. Both the linearity of the data and the closeness of the obtained yield to that estimated previously confirm the validity of the conducted survey. This emphasizes the fact that the oil yield in Hebron (south) is lower than that in the middle or north (Jenine and Nablus).

Similar to oil yield data, the obtained fitting R² values are high (almost above 0.99) confirming linearity. The fraction of solid waste (quantity of solid waste produced per quantity of processed olives) has an average value of 0.40. Relatively, olive mills in Hebron area produce larger fraction of solid waste compared to those in the north areas. While as they provide lower oil yield.

In olive mills, wastewater is generated from various sources including water coming from olives and water used for processing (water consumption). The latest source comes from two different steps; washing of olives and extraction of oil. The designed questionnaire enabled us to gather data for total wastewater, water used for washing and water used in extraction. The summation of water used for washing and extraction provided data for water consumption, while the difference between total wastewater and water consumption provided data for water coming from fruit. The obtained results for the various forms of water are plotted against quantity of processed olives and presented in Figures 2, 3 and 4.

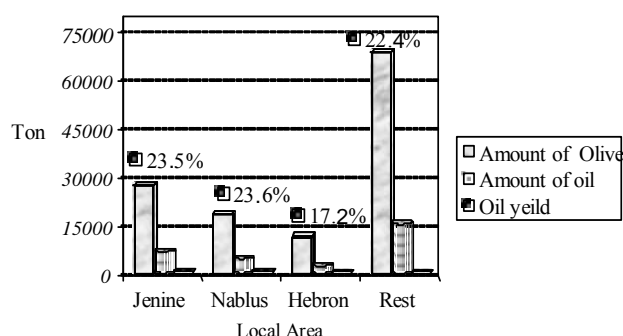


Fig. 1. Comparison of the amount of olives and olive oil produced in various parts of The West Bank and Gaza and the overall oil yield in the year 2002

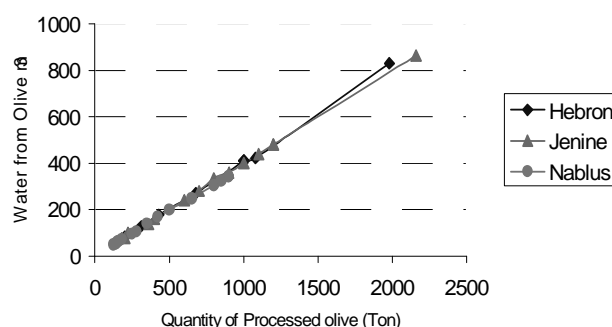


Fig. 2. Quantity of water coming from olive fruit versus quantity of processed olives for data from Hebron (triangles), Nablus (circles) and Jenine (diamonds)

Table 2

Results of linear curve fitting for data of water from olive fruit obtained from the conducted survey

Local area	Fitting line	Fitting R ²	Fraction of water coming from olive fruits
Hebron	Y=0.411 X	0.9983	0.411
Nablus	Y=0.382 X	0.9991	0.382
Jenine	Y=0.401 X	0.9992	0.401
All data as one plot (Average)	Y=0.398 X	0.9988	0.398

Figure 2 represents the obtained data of water coming from olive fruit versus quantity of processed olives, in Hebron, Nablus and Jenine. Obviously, the general trend is linear, the slope of which provides a representative value of the fraction of water content in the olive fruits. Table 2 provides the results of linear curve fitting for these data.

Similar to both oil yield and solid fraction, the obtained fitting R² values are all above 0.99. Relatively, olives in Hebron area contain slightly larger fraction of water than those in the north areas. In general, the fraction of water content in olive (quantity of water from olive fruit per quantity of processed olives) has an average value of nearly 0.4.

Table 3 summarizes the obtained characteristics of olives. From mass balance, the summation of the fractional oil yield, the fractional solid waste and the fractional water content in olives should be 1.0. With the obtained average values, the sum is 1.038 with

percentage error of 3.8%. Thus, these average values provide representative values for olives characteristic in Palestine with reasonable accuracy.

Figure 3 represents water consumption (for washing and extraction of oil) versus quantity of processed olive. Similar to other parameter, the trend is linear. Using linear curve fitting for these data provides fitting values (R²) all above 0.99 as listed in Table 4. The slope represents the average value of water consumption per ton of processed olives. The average value is 1.193 m³/ton. This value is relatively high, and it is of special concern in Palestine where water resources are very limited. Water consumption shall be minimized not only to reduce the generated wastewater, but also to reduce fresh water demand. This would require a technical review for operation of olive mills.

The average value is nearly 1.7 m³ wastewater/ton olives. This value is within the range of 1.2- 1.8 m³/ton published in the literature as the range of OMW

Table 3
Summary of typical olive characteristics in Palestine

Local area	Fraction of oil	Fraction of solid	Fraction of water	Total
Hebron	0.219	0.429	0.414	1.062
Nablus	0.248	0.399	0.382	1.029
Jenine	0.243	0.379	0.401	1.023
Average	0.237	0.403	0.398	1.038

Table 4
Results of linear curve fitting for water consumption data

Local area	Fitting line	Fitting R^2	Fraction of consumption water
Hebron	$Y=1.230X$	0.9907	1.230
Nablus	$Y=1.188X$	0.9945	1.188
Jenine	$Y=1.155X$	0.999	1.155
All data as one plot (Average)	$Y=1.191X$	0.9947	1.191

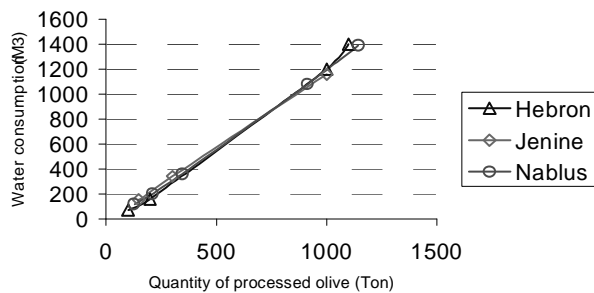


Fig. 3. Quantity of consumption water versus quantity of processed olives for data from Hebron (triangles), Nablus (circles) and Jenine (diamonds)

for continuous processes. For discontinuous processes, the range is 0.4 -0.5 m³/ton. In Palestine, as indicated in the introduction, the operations are split between continuous and discontinuous processes. However, the average value of the volume of OMW in Palestine fits within the range for continuous processes (which generates almost three times more wastewater than discontinuous processes). It is also more close to the maximum limit of that range. Consequently, it is important to perform technical review for the implemented technology and procedures fol-

lowed in Palestinian olive mill to reduce the rate of wastewater generation. Table 5 summarizes the results for water consumption and wastewater.

In Hebron area, although the levels of production of olives and olive oil are lower than those in the north, both water consumption levels and the total wastewater levels are higher than those in north areas. This indicates that the environmental concerns in Hebron are still considerable. Figure 4 indicates that washing water in Hebron is comparable to that in north area. Thus, the rise in the total wastewater in Hebron comes from the high relative water content and high level of water used for extraction.

Figure 5 presents plots of the total wastewater versus quantity of produced oil. Obviously, the curve for Hebron is above the other two curves for Jenine and Nablus. In addition to the previous reasoning regarding wastewater, the oil yield is lower, which contributes in raising this curve above the other ones.

The results of the experimental work for the obtained typical characteristics of olive mills wastewater are tabulated in Table 6. The obtained values at three intervals (beginning, middle and end of the harvest season) are listed and compared to the Jordanian stan-

Table 5
Summary of results of wastewater from olive mills

Local area	Water consumption ^(*)	Water coming from olive ^(*)	Total wastewater ^(*)
Hebron	1 230	0.411	1.641
Nablus	1 188	0.382	1.570
Jenine	1 155	0.401	1.556
All data as one plot (Average)	1 191	0.398	1.589

^(*) m³ water / ton olives

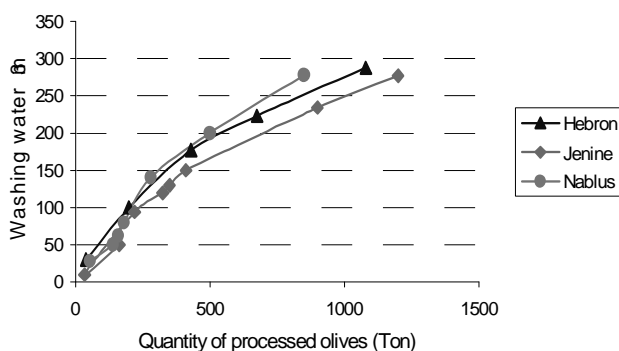


Fig. 4. Quantity of washing water versus quantity of processed olive for data from Hebron (triangles), Nablus (circles) and Jenine (diamonds)

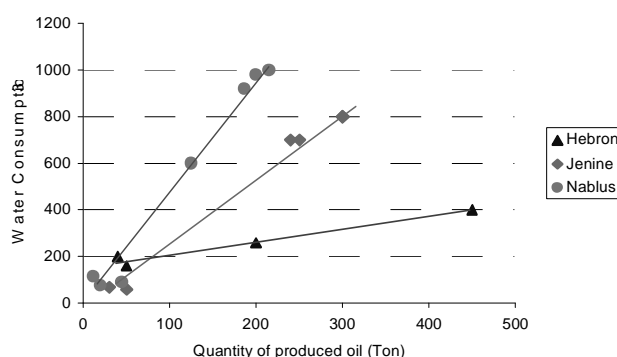


Fig. 5. Quantity of total wastewater versus quantity of produced oil for data from Hebron (triangles), Nablus (circles) and Jenine (diamonds)

dards for OMW for discharge to sanitary systems.

The obtained results indicate that there are some variations forms time to time during the season However; the investigation of these variations requires more extensive analysis and larger amount of data which is the subject of a subsequent paper by the authors. In this paper, the average values for the investigated characteristic parameters are considered. Obviously, other than the pH-value, other comparable values are all above the permitted values and thus the discharge of such OMW violates these standards and shall receive sufficient attention from authorities to encounter the environmental problem. Currently, the authors of this paper formulate a research team for demonstrating the applicability of Upper Flow Anaerobic Sludge Blenkt for minimizing the environmental impacts of OMW. A pilot plant is established as demonstration

project funded by USAID, and is functioning well. Comparing these obtained data with the published data (from Jordan) as tabulated in Table 1, indicates that the chosen olive mill generates wastewater with characteristics within the range of characteristics of OMW in Jordan.

Conclusion

This is paper highlight the environmental concerns associated with olive oil production in Palestine. The conduct survey reveals that there are local variations in the investigated parameters due to variations in the types of olives. Oil and water content in olives are dependent on location. The olives in the south are found to contain larger solid content than those in either middle or north, resulting in lower oil yield and

Table 6
Experimental results of OMW characteristics for sample obtained at the beginning, middle and the end of harvest season (2002)

Parameter	Unit	Value				Maximum Allowable Limit- Jordanian Standards (Discharge to sanitary systems)
		Beginning	Middle	End	Average	
pH	SU	4.8	5.08	5.1	4.99	5.5-9.5
COD	Mg/L	7121	6190	6815	6708.7	1100
BOD ₅	Mg/L	88535	98882	109582	98999.7	2100
TSS	Mg/L	42667	45680	48527	45624.7	800
TDS	Mg/L	11271	17335	22285	16963.7	
FOG	Mg/L	39063	27437	39138	35212.7	50
Phenol	Mg/L	3361	3363	4466	3730	10
EC	µs/cm	287	198	228	237.7	
T-P	Mg/L	648	348	587	527.7	
Tkj-N	Mg/L	3057	3087	3304	3149.3	

higher solid generation per ton of olive produced. The overall results indicate that the oil yield is nearly 23.7%, the fractional solid waste generation is nearly 0.4 while the remaining balance is nearly the water content in the olive fruit.

A representative value at 1.7 m³/ton for wastewater generation is found to be high compared to those values in other places of the world which requires technical review at the technology and operation of olive mills in Palestine. The characteristics of OMW are found to violate the standards for OMW which requires the attention of authorities.

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