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Implementation of Hazard Analysis Critical Control Points System (HACCP) During Extraction of Olive Oil by Hydraulic Press

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ABSTRACT

Olive oil is extracted from fruits of the olive tree which considered as one of the most important fruit crops in Egypt. HACCP system is an international system for food safety. So, the present work was carried out to investigate the possibility of implementation of HACCP system during olive oil extraction using hydraulic press to improve the quality and safety of olive oil production. The control measures and monitoring procedures for extraction olive oil were suggested. The microbial quality of studied samples from different processing steps and swabs from worker's hands and surface equipment's were used as criteria of food safety in this work. Aerobic bacterial count, yeast and mold count, coliform group and spore forming bacterial counts were analyzed to identify the sources of potential microbial hazards presenting in the various extraction steps of olive oil. The obtained results showed that, there were different biological, chemical and physical hazards in the raw material used in olive oil extraction. At the same time, contamination from equipment's and the lack of adequate personal hygiene practice for workers in the extraction plants were identified as others sources of hazards. A documented training in personal hygiene, good manufacturing practices (GMPs), cleaning and sanitation procedures and personal safety in addition to the rearrangement of the infrastructure of the extraction plant under investigation could improve yet more the quality and safety of olive oil extraction plant. HACCP system can be also used to control the safety and quality of olive oil extraction plant.

Key words: GMP, Hazard, HACCP, Hydraulic press, Quality, Olive oil, Safety

Introduction

Olive (*Olea europea* L.) belongs to family *Oleaceae* is considered as one of the most important fruit crops in Egypt. Olive is accepted by world health organizations as an important source of nutrition, makes a significant contribution to the economy and the agriculture of olive cultivating nations. The Mediterranean countries, where the olive tree has been cultivated for thousands of years, are still responsible for over 90% of the world's olive oil, (Bianchi, 2002). Today, the biological and nutritional values of virgin olive oil and its tangible effects on human health are widely acknowledged, (Alarcón de la Lastra *et al.* 2001). So olive oil, which has been a staple delectable food in the Mediterranean area for thousands of years, has become more popular than ever in many countries, (Ranalli *et al.* 2003). Virgin olive oil is defined as that the oil obtained from the olive fruit through physical procedures, which include washing, grinding, mixing, pressing, decantation, centrifugation or filtration, without being mixed with oils of another nature. The quality of virgin olive oil is directly related to the quality of the fruit from which it is extracted, (José and Yousfi, 2006). Olive oil extraction process is affected by handling operation and various practices during manufacturing which may sometimes cause some risks and damage that effect the olive oil quality. So it was interest to follow HACCP system in the olive oil extraction processes to identify and control these risks to produce a high quality, healthy and safety product. Today, with the progress of food quality and safety systems, HACCP has become synonymous with food safety. It is a worldwide recognized systematic and preventive approach that addresses biological, chemical and physical hazards through anticipation and prevention rather than through end-product inspection and testing, (Gandhi, 2008). Essentially, HACCP is a system that identifies and monitors specific foodborne hazards (biological, chemical, or physical properties) that can adversely affect the safety of the food product. This hazard analysis serves as the basis for establishing critical control points (CCPs). CCPs identify those points in the process that must be controlled to ensure the safety of the food. Further, critical limits are established that document the appropriate parameters that must be met at each CCP. Monitoring and verification steps are included in the system, again, to ensure that potential risks are controlled. The hazard analysis, critical control points, critical limits, and monitoring and verification steps are documented in a HACCP plan. Seven principles have been developed which provide guidance on the development of an effective HACCP plan.

So, the present work was carried out to investigate the possibility of implementation of HACCP system in olive oil extraction by hydraulic press to improve the quality and safety of olive oil.

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Material and Methods

Materials

Olive fruits

The olive fruits (Olea Europe) of Picual cultivar from 2010- 2011 crop obtained from Marsa Matrouh governorate were used in olive oil production.

Sampling

Samples were taken from the olive oil extraction process plant by hydraulic press method; including olive fruits, water, and olive paste from different steps during extraction process. Different samples were selected randomly, put into sterile plastic bags or bottles, then transported to the laboratory in an insulated and refrigerated box. The samples from processing surfaces and hands of plant workers were taken by swab method according to Stinson and Tiwari (1978).

Methods

Microbiological analysis

Olive fruits and olive paste

Samples of olive fruits and olive paste were examined for their total aerobic bacterial count, (ISO 4833, 2003), spore forming bacterial; yeast and mold counts (ISO 21527, 2008), coliform group (ISO 4832, 2006). All previous tests were used to reflect the microbiological quality of the olive fruits and olive paste.

Water samples

Water samples were examined for their total aerobic bacteria count and coliform group. The results of these tests were used to reflect the hygienic state of water used in different olive oil extraction plants.

Swab samples

Swab samples were tested for total aerobic bacterial count and coliform group. The results of these tests were used to reflect the hygienic state of the employers, utensils and equipments.

Different samples were aseptically removed from the plastic bags or bottles, 10 g or 10 ml from each was homogenized in 90 ml of sterile diluents (0.1% peptone water) with a Stomacher for 30 Sec. Serial dilutions were prepared in peptone water and 1ml aliquots were plated in each specific medium which obtained from and incubated at different temperatures as listed in Table (1).

For aerobic spore forming bacterial count, serial dilutions of different samples were pasteurized in autoclave at 110°C for 10 min and 1 ml aliquots were plated in the medium as listed in Table (1).

Table 1: Media and incubation conditions used for microbiological analysis

Microbiological analysis	Incubation		
	Time (h)	Temp (°C)	Growth medium
Total aerobic colony count	48	37	Plate count agar
Aerobic spore forming bacterial	48	37 and 55	Plate count agar
Yeast and mold count	72	25	Potato dextrose agar
Coliform group	24 – 48	37	Vilot red bile agar

Air samples

Settling plates were carried out to evaluate the microbiological load of air in different locations through olive oil extraction processing line under investigation. The sterilized Petri plates (Standard size of 90 mm diameter) which contained about 15 ml of the selective media were distributed through different locations on processing lines and then left to exposure to air for 15 min. After exposure, plates were incubated according to the appropriate procedures then, the colonies were counted as colony forming unit (cfu) per 15 min for each area, (A.O.A.C, 2007).

Olive oil extraction

The extraction steps of olive oil using hydraulic press were viewed in Fig. (1). The processing steps are olive fruits receiving, leaves removing, olive fruits washing, olive crushing and olive paste malaxation.

Olive oil characteristics

Acidity (% as oleic), peroxide value and fatty acids of extracted olive oil samples were determined according to A.O.A.C. (2007) methods. K_{232} (Ultra-Violet absorbance at 232nm) and K_{270} (Ultra-Violet absorbance at 270nm) were determined as A.O.A.C (2007) method. Polyphenols were determined according to Gutfinger (1981) method. TBA value was determined by Sidwell *et al* (1954) method.

Listing the prerequisite programs

The prerequisite programs (PRPs) represent the conditions and/or the necessary basic activities to develop the seven principles of HACCP system during olive oil extraction in the olive oil extraction plant under investigation were evaluated according to (E.S: 3393, 2005b).

Application of HACCP system

According to the NACMCF (1992 and 1998), HACCP system was applied during extraction steps of olive oil by hydraulic pressing method based in the following seven principles: 1) Conduct a hazard analyses. 2) Identify the critical control points (CCPs). 3) Establish critical limits for preventive measures associated with each identified CCP. 4) Establish CCP monitoring requirements.5) Establish corrective actions to be taken when monitoring indicates then a deviation from an established critical limit. 6) Establish verification procedures. 7) Establish record-keeping and documentation procedures. The results were summarized with reference to CCPs and their monitoring on the HACCP worksheet.

Results and Discussion

Listing the prerequisite programs (PRPs)

The results of PRPs (un tabulated data) represent the conditions and/or the necessary basic activities to maintain a hygienic environment for the different extraction steps of olive oil plant under investigation should be established in the plant before application of HACCP system which determined using chick list according to E.S: 3393/2005b. It could be noticed that, location of extraction plant, walls, devices and machines and disposals tanks were satisfactory according to the criteria listed in E.S: 3393/2005b. On the other hand, for more controlling of microbial contamination during different extraction steps of olive oil by extraction plant under investigation, the following areas in the extraction plant should be physically separated: olive reception, washing, oil extraction and separation, oil storage and packaging (Petrakis, 1994). At the same time, quality control practices and its device were not applicable where the temperature of the olive oil extraction plant was not recorded and the microbiological characteristics of water used in the olive oil extraction plant were not evaluated and the safety of water used in the extraction plant was not determined, this could be one of the major contamination sources during extraction steps. Also, the operation control was not applicable, so, we suggested a simple HACCP system for operation control. Maintenance and sanitations were not applicable where program of pest control was not applicable and there is no program for waste management of wastes produced during extraction process. According to the results observed of personal hygiene of workers in the extraction plant under investigation it could be noticed that, hygiene and sanitation practices of workers in the extraction plant were not enough and workers should learned more about personal hygiene especially washing their hands with soap and sanitizers after toilet.

Application of HACCP system in olive oil extraction using hydraulic press plant

Hazard analysis

Typical preparation, associated hazards, and critical control point of different extraction steps of olive oil extracted by hydraulic press are illustrated in flow diagram Fig. (1). The possibilities of contamination, survival of contaminants, and growth of microorganisms are analyzed in process reviews. Sources of contamination are worker's hand, utensils, equipments and raw materials.

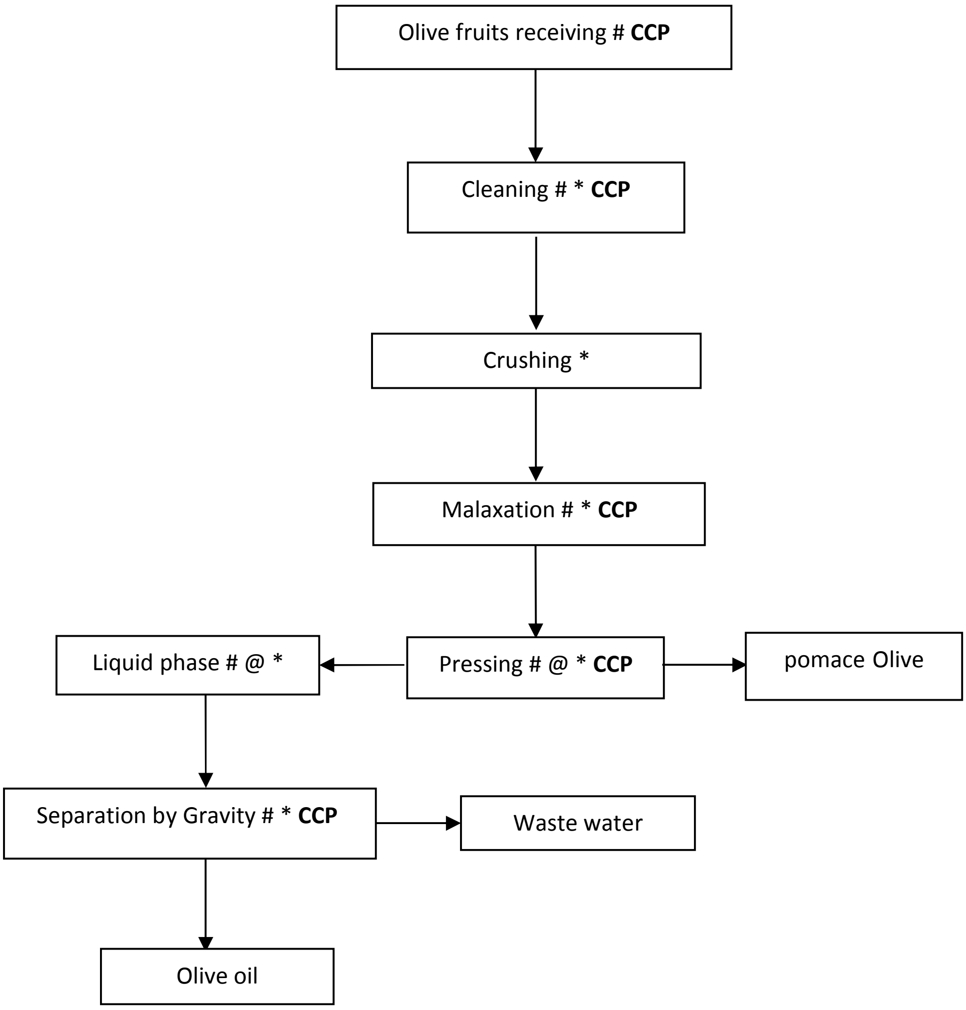

Fig. 1. Flow diagram of the extraction olive oil by hydraulic press method.
*CCP = Critical Control Point, # = Possible contamination, * = Contamination from equipment and utensil surfaces and @ = Contamination by persons handling product*

The obtained results of microbiological loads of air from different locations surrounded the olive oil extraction plant under investigation are shown in Fig. (2).

From the presented data it could be noticed that the total aerobic count of collected air samples ranged between 1.81 and 1.94 log cfu/plate for hydraulic press plant. Where there are no microbial criteria of air in the food establishment, these results could be used for reflecting the microbiological quality of air in the extraction plant under investigation as it could be noticed that, the microbiological quality of air of olive oil extraction plants area was satisfactory.

Water is an important factor in olive oil extraction plants because it was used in washing olive fruits, equipments, utensils and hands of workers and as raw material in the oil separation process.The results of microbiological analysis of water sample collected from hydraulic press plant are demonstrated in Fig. (3).

Data recorded in Fig. (3) showed that the content of total aerobic bacterial counts and coliform groups in water sample used in hydraulic press plant were higher than the required limits of E.S: 1589 (2005a) which stated that water used in food must have no more 20 cell of total aerobic bacterial count without any cell of coliform group. This may be due to that the water line of hydraulic press is old and may have many disorders caused this contamination. This point was listed as major contamination source and should be corrected by maintains the water line supply of extraction plant and periodic microbiological analysis of the used water.

The obtained results of the microbiological analysis of the swabs from workers in the hydraulic press plant are shown in Table (2).

Swabs of worker's hands were tested for total aerobic bacterial count and coliform group as microbiological criteria for the evaluation of personal hygiene. According to the result in Table (2), it could be noticed that, total aerobic bacterial count of swab from worker's hands ranged from 0.85 to 2.28 log cfu/cm2. On the other hand, coliform group was not detected in the swabs of worker's hands in feeding and washing steps, but swabs of workers in crushing and malaxation and pressing steps contained coliform group with values of 0.32 and 0.95 cfu/cm2, respectively. The presence of coliform group in the hands of workers may be regarded to poor personal hygiene of workers during processing steps and this could be solved by planning a training program for workers in the plant under investigation about good personal hygiene during the extraction steps of olive oil. At the same time, the personal hygiene one of the prerequisite program should be established in the plant for application HACCP system.

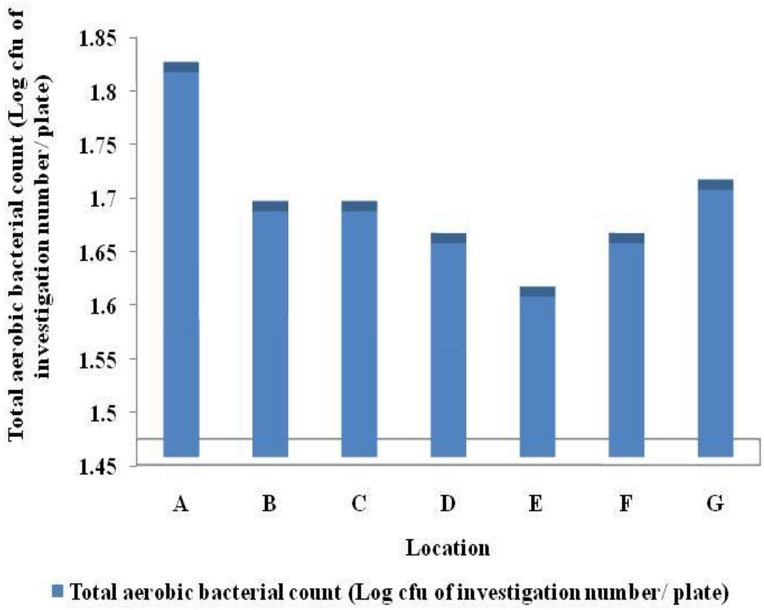

Fig. 2: Total aerobic bacterial count of air samples collected from hydraulic press plant.

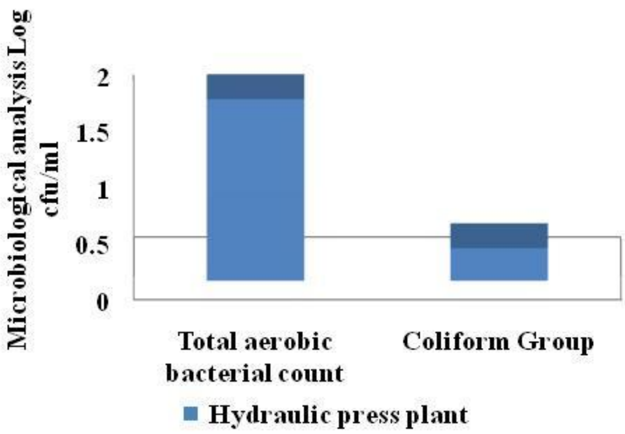

Fig. 3: Microbiological analysis of water samples collected from hydraulic press plant

The microbiological analysis (total aerobic bacterial count and coliform group) of swabs of hydraulic press extraction plant equipments was determined and the results are tabulated in **Table (3)**. From the presented data, it could be noticed that, total aerobic bacterial count of washing tank, olive crusher, malaxation 1, malaxation 2, hydraulic press and pressing stainless disk was 1.65, 1.70, 1.66, 1.88, 1.94 and 2.40 log cfu/cm^2, respectively. About coliform group which used as sanitation criteria, it could be noticed that, it was not detected at detection limit < 10^1 cfu/cm^2 in washing tank, olive crusher and malaxation tank 1. On the other hand, malaxation tank 2, hydraulic pressure and disk equipment's had values of coilform group being 0.85, 2.00 and 1.74 log cfu/cm^2, respectively. This microbiological load may be due to the absence of detailed plan for cleaning and disinfection processes for equipment's and tools used in hydraulic press plant, therefore a planned cleaning and disinfection program of equipment used in the extraction plant under investigation should be used and verification its performance periodically.

Table 2: Microbiological analysis of different swabs from hands of workers in hydraulic press plant

Workers	Microbiological analysis Log cfu/cm^2	
	Total aerobic bacterial count	Coliform Group
Worker in feeding step	0.85	<1
Worker in washing step	1.93	<1
Worker in crushing and malaxation step	1.88	0.32
Worker in pressing step	2.28	0.95

<1: viable colony was not detected at detection limit < 10^1 cfu/ cm^2

Table 3. Microbiological analysis of different swabs from equipments used in hydraulic pressing plant:

Equipment	Microbiological analysis Log cfu/cm^2	
	Total aerobic bacterial count	Coliform Group
Washing tank	1.65	<1
Olive crusher	1.70	<1
Malaxation 1	1.66	<1
Malaxation 2	1.88	0.85
Hydraulic pressure	1.94	2.00
Disk	2.40	1.74

<1: viable colony was not detected at detection limit < 10^1 cfu/cm^2

The microbiological analysis of different steps during olive oil extraction by hydraulic press plant was determined and the results are presented in Table (4).

The main extraction steps were investigated for their contents of total aerobic bacterial count, coliform group, yeast & mold count and aerobic spore forming bacterial count. From the data in Table (4) it could be observed that, the total aerobic bacterial count decreased from 4.76 log cfu/g for olive fruits before washing to 3.89 log cfu/g after washing, then it decreased to 2.60 log cfu/g after crushing step, which may be due to the events of mechanic damage to microbial cell walls during crushing process. While, the total aerobic bacterial count increased during malaxation steps 1 and 2 comparing to olive paste sample after crushing step where it was 4.40 log cfu/g during malaxation 1 and 4.73 log cfu/g during malaxation 2. The same trend was observed for yeast & mold count, which decreased from 4.26 log cfu/g for olive fruits before washing to 2.95 log cfu/g after washing, then it decreased to 2.60 log cfu/g after crushing step. On the other hand, yeast & mold count increased during malaxation steps 1 and 2 comparing to olive paste sample after crushing step where it was 2.85 log cfu/g during malaxation 1 step and increased to 2.95 log cfu/g during malaxation 2 step. Concerning the results of coliform group, it increased from 2.18 log cfu/g for olive fruits before washing to 2.30 log cfu/g after washing (as a result of unsuitable range of washing water replacing), then it decreased to 2.26 log cfu/g during crushing process, which may be due to the events of mechanic damage to microbial cell walls during crunching process. Also, coliform group increased during malaxation 1 and 2 steps comparing to olive paste sample after crushing step, where it was 3.00 log cfu/g during malaxation 1 and 2 steps.

Table 4. Microbiological analysis of different extraction steps of olive oil by hydraulic press plant:

Extraction steps	Microbiological analysis Log cfu/g			
	Total aerobic bacterial count	Coilform group	Yeast & Mold count	Aerobic spore forming bacterial count
Olive fruit before washing	4.76	2.18	4.26	2.43
Olive fruit after washing	3.89	2.30	2.95	2.19
Olive past during crushing	2.60	2.26	2.60	2.04
Olive paste during malaxation 1	4.40	3.00	2.85	2.08
Olive paste during malaxation 2	4.73	3.00	2.95	2.38

From the same table, it could be noted that, aerobic spore forming bacterial count decreased from 2.43 log cfu/g for olive fruits before washing to 2.19 log cfu/g after washing, and it also decreased to 2.04 log cfu/g during crushing process, which may be due to the events of mechanic damage to microbial cell walls during crushing process. Thereafter, the aerobic spore forming bacterial counts increased during malaxation 1 and 2 steps comparing to olive paste sample after crushing step where it was 2.08 log cfu/g during malaxation 1 and 2.38 log cfu/g during malaxation 2. According to the aforementioned results it could be concluded that, washing step was very important in reducing the microbial load of olive fruits and could be determined as one of the critical control points during the processing steps of olive oil extraction by hydraulic press method and the characteristics of water used in this step was a control measures which should be established. At the same time, malaxation step should be controlled especially during malaxation step 2 as one of the reasons of increasing the microbial load of olive past, therefore, establishment a good sanitation program of the aforementioned equipments could be used as control measures during application of HACCP system during extraction process.

Physicochemical parameters of olive oil produced by hydraulic press system:

The results of physicochemical parameters of olive oil extracted by hydraulic pressing system are summarized in Table (5). From the obtained results in Table (5) it could be noticed that, acidity (1.46% as oleic acid) of the produced oil by hydraulic press was in the allowed limits of olive oils to be categorized as virgin olive oil according to the codex standards (Codex/RS 33-Rev. 2-2003b) in relation to acidity. The commonly used methods for measuring the auto-oxidation statues of oil are the formation of peroxides and thiobarbituric acid (TBA) test. The first parameter gives a whole picture of the course of oil oxidation, whilst, the second presents the production of secondary oxidation products, which are responsible for off flavors of rancid oil (Basuny, 1996).

Table 5: Physicochemical properties of olive oil extracted by hydraulic press system

Parameters	Extracted olive oil	Egyptian standard*	Codex standard**
Acidity (% as oleic)	1.46 ± 0.025	3.3	3.3
Peroxide value (meq peroxide / kg oil)	10.26 ± 0.157	≤ 20	≤ 20
TBA (mg malonaldhid / kg oil)	1.86 ± 0.025	-	-
K_{232}	2.17 ± 0.064	-	3.5
K_{270}	0.45 ± 0.015	0.25	0.3
Polyphenols (as ppm gallic acid)	300 ± 5	-	-

** Egyptian standard of vegetables edible oils (2000), ** Codex standard (2003b), ± SD, K_{232} (Ultra-Violet absorbance at 232nm) and K_{270} (Ultra-Violet absorbance at 270nm).*

In relation to the peroxide value of olive oil, (only this was allowed to have peroxide value reaches to 20 because it contains desirable bio-active materials which interfere in determination of peroxide value). It could be noticed that the extracted oil using hydraulic press had high peroxide value (10.26), it means that, oil oxidation takes place in this sample. From the results shown in Table (5), the TBA (as mg malonaldhid / kg oil) recorded a high value reached to 1.86, it means that the secondary oxidation of the oil had been occurred. From the aforementioned results of K_{232} and K_{270} [K_{232} value measures the primary oxidation whereas the secondary oxidation could be measured by K270 (Ranalli *et al* 2000)], their values were 2.17 and 0.45, respectively. The K_{232} did not reach to the allowed values by codex standards (Codex/RS 33-Rev. 2-2003b) which stated the max value of K_{232} is 3.5 for olive oil to be categorized as virgin olive oil. But K_{270} was higher than the max value of standards (0.3). The results of peroxide value and TBA are in agreement with those of K_{232} and K_{270}. These results indicated that oil oxidation had happened not only primary oxidation but also, secondary oxidation. The data in Table (5) showed that, the total poly phenols (as ppm gallic acid) were 300 ppm. This may be due to the used extraction system (hydraulic press) which required high amount of water to separate the olive oil.

Fatty acid composition of olive oil extracted by hydraulic press system

Data recorded in Table (6) showed the results of fatty acid composition of olive oil extracted by hydraulic press system. It was obviously clear that, olive oil extracted by hydraulic press system had a unique fatty acid profile. The dominated fatty acids in this oil are oleic (63.10 %), linoleic (13.04 %), linolenic (0.99 %), palmitoleic (1.91 %), palmitic (16.40 %) and stearic (2.81 %). The unsaturated oleic acid presented the highest quantity (63.10 %), (Santinelli *et al* 1992). Also, the results of fatty acids presented in Table (6) illustrated that, all measured fatty acids were in the required limits for both Egyptian and Codex standards for olive oil with one exception related to Linolenic (C18:3) which was slightly higher (0.99%) than the limits of the two standards (0.90). Generally, there are two most important parameters related to fatty acid composition of any oil, the first is the ratio of sat/unsat, which related to the oxidation stability of the oil, while the second is oleic/linoleic ratio which has a positive effect on the taste of oil (Ranalli *et al* 2001). From the above results it could be concluded that, olive oil extracted by hydraulic press had weak stability for oxidation (sat/unsat 0.25). Also, this oil had low degree in the taste acceptability (oleic/linoleic ratio was 5).

Identify critical control points

A Critical Control Point (CCP) refers to a step, or procedure in a food process at which an essential control measure can be applied to eliminate, prevent or reduce an identified food hazard to an acceptable limit, (ISO 22000-2005). Each CCP has one or more critical limits to ensure that hazards are prevented, eliminated or reduced to an acceptable level. During a flow diagram's checking procedure using the decision tree, (codex 2003a), several critical control points have been set up and tabulate in Table (7).

Table 6: Fatty acid composition of olive oil extracted by hydraulic press system

Fatty acid	Extracted olive oil	Egyptian standard *	Codex standard **
Palmitic C16:0	16.40	7.5 – 20.0	7.5 – 20.0
Heptadecanoic C17:0	0.04	0.0 – 0.3	0.0 – 0.3
Stearic C18:0	2.81	0.5 – 5.0	0.5 – 5.0
Arachidic C20:0	0.59	0.0 – 0.6	0.0 – 0.6
Behenic C22:0	0.12	0.0 – 0.2	0.0 – 0.2
Lignoceric C24:0	0.05	0.0 – 0.2	
Total saturated	20.01		
Palmitoleic C16:1	1.91	0.3 – 3.5	0.3 – 3.5
Heptadecenoic C17:1	0.07	0.0 – 0.3	0.0 – 0.3
Oleic C18:1	63.10	55.0 – 83.0	55.0 – 83.0
Linoleic C18:2	13.04	3.5 – 21.0	3.5 – 21.0
Linolenic C18:3	0.99	0.0 – 0.9	0.0 – 0.9
Unknown	0.53	-	
Total unsaturated	79.92		
Sat/unsat. Ratio	0.25		
Oleic/ Linoleic ratio	5.00		

** Egyptian standard of vegetables edible oils (2000) and ** Codex standard (2003b)*

Set the critical limits for critical control points

The critical limits must be established to guarantee that; the acceptable level for each hazard at each CCP is not exceeded. During CCP identification, establish critical limits should be measurable where it could be reasonably demonstrated that the threshold level has not been exceeded. Critical limits may be based upon factors such as: olive quality, water quality, adequate renew frequently wash water, good hygiene, good performance of equipment, temperature and time, good personal hygiene and some physicochemical properties of olive oil such as FFA, PV, TBA, K_{232}, K_{270} and Polyphenols.

Establish monitoring procedures for the critical control points

Planned observations and measurements were conducted to assess whether a CCP was under control and produce an accurate record for a future verification process. Monitoring action during olive oil extraction were included, visual inspection of each items, microbiological and physicochemical analysis of water, physicochemical properties of olive oil (FFA, PV, TBA, K_{232}, K_{270} and Polyphenols), chemical analysis of samples, visual inspection of wash water dirt, temperature and time, periodic visual inspection of equipment, correct application of the programs preventive cleaning and disinfection of equipment and good hygiene practices.

Establish a corrective action

During investigation of olive oil extraction plant some specific corrective actions were established for each identified CCP. These corrective actions were performed when the monitoring procedures had been indicated that, the critical limits were exceeded. The corrective actions were designed to rapidly regain control over the CCP and prevent recurrence. Corrective action during extraction olive oil should include: reject unsuitable items, poor quality fruits must processed separately, switch point water supply, conduct training for operators, increase changes wash water, visual inspection of temperature and time and correct preventive programs for maintenance, equipment cleaning and disinfection.

Establish verification procedures

Validation, verification and review of established HACCP plan were established during the investigation of olive oil extraction plant. The verification procedures were established in order to check if the HACCP system is working as HACCP plan; this could be done by establishing accurate records of the previous and ongoing measurements as well as the tracking of those products that exceeded the critical limits. These verification procedures were including: develop particular specifications for the product, recording raw materials, frequency of changes water, preventive programs for maintenance, equipment cleaning and disinfection and corrective measures.

Table 7. CCP determination for Olive oil extraction by Hydraulic pressing system

Processing step	Category and identified hazard	Q1	Q2	Q3	Q4	CCP
Receiving of olive fruits	Microbiological infection (B)	No	No			CCP
	Suitability of olive (P&B)	Yes	Yes			
	Mechanical damage (P)	No	Yes	*		
	Insect infection (P)	No	Yes	**		
	Foreign materials(P)	No	No			
	Pesticides residues (C)	No	Yes	***		
	Enzymatic reactions (C)	Yes	Yes			
Cleaning (leaves removal, washing)	Water quality (B)	Yes	Yes			CCP
	Reuse of excessive wash water (B)	Yes	Yes			
	Washing time (B)	Yes	Yes			
	Foreign materials (P)	Yes	Yes			
Crushing	Microbiological infection (B)	No	No			
	Foreign materials (P)	No	No			
Malaxation	Microbiological infection (B)	Yes	Yes			CCP
	Emulsions formation (C)	Yes	Yes			
	Enzymatic reactions (C)	Yes	Yes			
Extraction of olive oil by hydraulic press	Microbiological infection (B)	Yes	No	No	No	CCP
	Personal hygiene (B)	Yes	No	Yes	No	
	Water quality (M)	Yes	Yes			
	Enzymatic reactions (C)	Yes	Yes			
	Emulsions formation (C)	Yes	Yes			
Separation by gravity	Impurities (P)	Yes	Yes			CCP
	Enzymatic reactions (C)	Yes	Yes			
	Yes	Yes				

*B=Biological, C=Chemical, P=Physical, *= Modifying (Sorting), **=Modifying (Insect control program) and ***=Modifying (Safety period) From the aforementioned data, it could be noted that, receiving olive fruits, cleaning olive fruits, malaxation, extraction of olive oil and separation of olive oil were CCPs*

Instructions:

• Q1: Do control preventive measures exist, if no, not CCP; if yes proceed to next.
• Q2: Is this operation specifically designed to eliminate, if no proceed to Q3. If yes CCP and identify it in the last column.
• Q3: Could contamination with identified hazards occur in excess of acceptable levels, if no, not CCP. If yes proceed to Q4.
• Q4: Will subsequent operation control the contamination levels, if no CCP; if yes not CCP.

The different aforementioned principles of designed HACCP plan during the investigation of olive oil extraction plant are tabulated in Table (8).

Table 8: HACCP work sheet for Hydraulic press system.

Critical control point (CCP)	Hazard	Control measures	Critical limits	Monitoring action	Corrective action	Verification procedures and documentation
Receiving of olive fruits	*Microbiological infection *Insect infection *Suitability of olive * Mechanical damage *Pesticides residues *Heavy metal *Enzymatic reactions *Foreign materials	*Cleaning efficiency *Separate ground of flight and health olives *High quality drinking water *Good transportation handling	*Separation of ground of flight and health olives *Meeting the specifications of drinking water *Adequate sanitary conditions *Good transportation	*Visual inspection of each items *Microbiological and physicochemical analysis of water *Chemical analysis of samples	*Reject unsuitable items *Poor quality fruits must processed separately *Switch point water supply *Conduct training for operators	*Develop particular specifications for the product *Corrective measures *Recording raw materials

Curr. Sci. Int. 2(2): 30-41, 2013

Cleaning (leaves removal, washing)	*Water quality *Foreign materials *Washing time *Reuse of excessive wash water	*Program effectiveness cleaning and disinfection *Renew frequently wash water *Equipment	*Adequate renewal of the washing water *Increase wash time *Good hygiene *Good performance of equipment	*Visual inspection of wash water dirt *Correct application of the programs preventive cleaning and disinfection of equipment	*Increase changes wash water *Correct programs preventive cleaning and disinfection of equipment	*Frequency of changes water * Programs preventive cleaning and disinfection of equipment *Corrective measures
Malaxation process	*Microbiological infection *Enzymatic reactions *Emulsions formation	*Equipment (state, cleaning) *Olive past temperature and malaxation time (<30ºC, 45min) *oil loss	*Good performance of equipment *Suitable conditions (25-30 ºC, 45-60 min)	* Malaxation temperature and time	*Visual inspection of malaxation temperature and time *Correct programs preventive cleaning and disinfection of equipment	* Cleaning and disinfection programs of equipment *Visual inspection of malaxation temperature and time

Continue **Table 8:**

Critical control point (CCP)	Hazard	Control measures	Critical limits	Monitoring action	Corrective action	Verification procedures and documentation
Extraction of olive oil by hydraulic pressing (liquid phase)	*Microbiological infection *Personal hygiene *Enzymatic reactions *Emulsions formation *Water quality	*Personal hygiene *Operations (time, efficiency, oil loss) *Water temperature and water count *Equipment (state, cleaning) *Cleaning program and adequate disinfections *Oil loss	*Good personal hygiene *Time processing * Water count (1/2 L/Kg past) *Water temperature (25-28 ºC) *Minimum oil loss	*Visual inspection of time processing, water count and water temperature	*Correct programs maintenance preventive cleaning and disinfection of equipment * Adjusting water count and temperature	* Preventive programs for cleaning and disinfection of equipment * Adjusting water count and temperature
Oil separation	*Impurities *Oil degradation *Microbiological infection *Enzymatic reactions	*FFA, PV, TBA, K_{232}, K_{270}, Polyphenols *Filtration suitable amount of water *Water temperature	*FFA, PV, TBA, K_{232}, K_{270}, Polyphenols *Olive oil specification *Good performance of equipment *Good hygiene *Good handling practices	*Visual inspection of FFA, PV, TBA, K_{232}, K_{270}, Polyphenols *Good hygiene practices *Periodic visual inspection of equipment	*Correct preventive maintenance programs, cleaning and disinfection of equipment *Conduct training to operators	* Preventive programs maintenance, equipment cleaning and disinfection *Training courses *Visual inspection of FFA, PV, TBA, K_{232}, K_{270}, Polyphenols

Conclusion

The main sources of hazards during olive oil extraction come from environment (tree–ground), handling and processing techniques. Olives may be contaminated by microorganisms, pesticides and heavy metal. Hygiene handling and good manufacturing practice during receiving of olives, washing and different extraction steps are very important, because many microorganisms and enzymatic reactions may be accrued and affected the safety and quality of olive oil. The establishment of HACCP system as Food Safety tools in the extraction plants of olive oil allows controlling of different hazards affecting the safety of consumers. Application of HACCP system could be used for harmonizing the practices of different HACCP principles for controlling the different identified hazards during different steps of olive oil extraction. Various microbiological methods of analysis and procedures have been developed to monitor the safety of olive oil at an early stage and during extraction steps. The PRPs implementation allowed us to master the likelihood of incidence of physical, chemical and microbiological hazards. The HACCP plan principles were established and have been enabled to monitor and control of identified microbiological hazards

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