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Integral centrifuges for olive oil extraction, at the third millenium threshold. Transformation yields.

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RESUMEN

Los decantadores centrifugos horizontales para la extracción de aceite de oliva a las puertas del tercer milenio. Los rendimientos de transformación.

El nuevo "decanter", a dos fases (capaz de centrifugar la pasta oleosa sin la dilución previa con agua caliente) ha sido confrontado con el de a tres fases, elaborando, a nivel industrial, partidas homogéneas de tres variedades de aceitunas (Coratina, Nebbio y Grossa di Cassano).

Los resultados de investigación han puesto de manifiesto que las centrifugadoras integrales permiten obtener, frecuentemente, rendimientos de extracción mas altos. Además, en relación con el hecho de que el agua de vegetación queda completamente incorporada en el orujo, la cantidad de flujo producido es muy bajo (en torno a 10 Kg/q aceitunas), lo que permite resolver desde la raiz el problema relativo al tratamiento de los efluentes de las almazaras.

Sin embargo, el orujo obtenido, resulta muy húmedo (55-60%), lo que hace difícil y costosa la explotación industrial. Esta, además, se caracteriza por el más alto contenido porcentual de aceite, por la mayor relación pulpa/hueso y por el hecho de que, en peso, la cantidad producida es mayor. El flujo, producido como se ha dicho anteriormente en cantidad mínima, aparece más concentrado y, por tanto, mas rico en grasa, residuo seco, fenol y o-difenol, y permite registrar valores más altos del COD y turbiedad.

Para terminar y como indicaremos en la segunda parte, los aceites resultan cualitativamente superiores, sobre todo por la mayor estabilidad oxidativa y por las mejores caracteristicas sensoriales, por lo que son del todo comparables a los aceites de presión y de percolamiento.

A ello se añade gue se debe resaltar la significativa reducción de los costes de transformación, en relación con la economía inherente al bajo consumo de agua y ahorro energético.

PALABRAS-CLAVE: *Aceite de oliva (extracción) — Decantador centrifugo horizontal — Transformación (rendimiento).*

SUMMARY

Integral centrifuges for olive oil extraction, on the threshold of the third millenium. Transformation yields.

A new-two, phase "decanter" (able to centrifuge the oily pastes without previous addition of hot water) was compared with a three-phase one, processing homogeneous lots of three olive varieties (Coratina, Nebbio and Grossa di Cassano) at an industrial level.

The results showed that the integral centrifuge frequently yielded higher oil outputs. Furthermore, as the vegetation water was not separated from the husk, the amount liquid effluent produced was much lower (about 10 Kg/q olives, on average). This goes towards solving the age-old and very difficult problems connected with the production of this highly polluting outflow.

However, the olive cake obtained semi-liquid (with about 55-60% of moisture), making the industrial recovery of the residual oil difficult and expensive. Furthermore, the solid by-product was characterized by higher percentage values of the oil amount, higher values of the pulp/stone ratio, as well as the greater weight produced.

The effluent produced in small quantities, besides being more concentrated and thus richer in fat, dry residue, phenols and o-diphenols. The COD and turbidity values were also higher.

Finally, as will be referred to in detail in the second part of this work, the oils obtained were of a far higher quality, mainly for their lower oxidizability and better organoleptic characteristic, so that they are wholly comparable to those extracted by pressing or filtering.

In addition, the significant reduction of processing costs, as well as the lower consumption of hot water and electrical energy, must also be emphasized.

KEY-WORDS: *Integral centrifuge — Olive oil (extraction) — Transformation (yield).*

1. INTRODUCTION

The classic olive oil extraction system, based on the combined use of pan crusher and hydraulic press, quite diffused at present day, has not permitted processing the olives in a continuous manner. Furthermore the transformation costs relating to it, have been rather high owing to the elevated labour requirements and the excessive expenses connected to the purchase and the breaking of the filtering diaphrams during the pressing step. These materials, which then absorb the oil, have negatively influenced the extraction outputs; but above all, because of the frequent contaminations due to the unavoidable processing of olive lots degraded, they have often caused a disqualification or declassing of the oil produced, notwithstanding the good quality of the drupes brought to the extraction. Finally, we would like you to note that operating by the traditional processing system has made the work very laborous so that it has been neither pleasant nor preferred by the workers.

The modernization of the extraction plants, the restructure of the oil-mills and the rationalization of the classic working system have only partially solved the above mentioned problems.

For these reasons, the necessity to find new technological solutions for the extraction of the oil from olives was felt. Essentially, the aim of the research is to replace the pressing strength with the centrifugal one. It seems interesting to, once again, run through the more significative historical stages which lead up to the construction of the industrial centrifugal plants.

A. Boullier (5) was the first experimenter, in 1902, to directly execute the extraction of the oil by the centrifugation of the olive paste. He used a basket centrifuge made in metal thread, with which up to 80% of the oil from olives, would have been able to be recovered. The processing water was used in the final stage of the centrifuging operation.

Two years after, always by means of a basket centrifuge, but with a bigger diameter, trials of oil extraction were carried out by the Agricultural Experimental Observatory of California (1). The results of this research were not better than the above ones.

In 1908 centrifugation experiments of the oily olive paste were carried out by F. Bracci (6). He also obtained a low percentage oil yield. The resulting husk appeared rich in fat and moisture.

In that same year, M. Morel-Revoil (26) published the results of his pluriannual experiments which were carried out by means of more powerful centrifuges. Such results could appear to be comparable with the ones of the classic system, and furthermore the oil produced showed a lower acidity. On the other hand, the loading and unloading of the centrifuge were too long and the paste centrifugation very slow. According to the author such a centrifugal system could be applied for a first paste extraction, followed by the pressing step so as to obtain the complete extractlon.

In 1926 the attempts of M. Degli Atti (17) followed. They are to be remembered only because they were carried out using a centrifuge with a conic section, rather than a cylindrical one.

In 1927 a new centrifuge, called "cyclone" was patented (10) by the California Packing Corporation. It was constituted by a working drum, made of metal thread, running at high speed and provided with a elix-shaped scraper, able to evacuate the husk (from it), which was then submitted to the pressing strength.

In 1929 the Spanish N. Ortiz (16) and the French M. Rousseau (38) experimented particular centrifuges, which had to be able to extract the oil from the olive pastes in a countinous way. But the results were not positive; nevertheless the above centrifuges were to be considered as a technological innovation because the liquid phases were separated from the paste according to a centripetal way.

Afterwards, in 1931, it was O. Ferraris's turn (12), who planned a centrifuge with a non perforated basket of an overturned-cone shape, from which the liquid phases were kept away from the upper part by means of resucking members.

This centrifuge type also afforded modest results.

In 1937 C. Pantanelli and E. Brandonisio (28) invented a centrifuge with a horizontal axle, characterized by a drum without holes and provided with a scraper whose results were considered good. These researchers diluted the olive paste with water (1:3 ratio).

In the 40's, C. Perogio tried again with the basket centrifuge, but with the use of some small horsehair sacks, as a filtering means, which were filled with the olive paste to be centrifuged. His proposal was submitted to the evaluation of a technical board nominated by the Italian Agriculture Ministry, who reached rather optimistic conclusions (39). But such results were denied by the data of the technological research, subsequently carried out by M. Valleggi (40).

In 1950 C. Tortorelli experimented a processing monoblock plant equipped with a centrifuge, whose axle was able to run at a speed of up to 900 rpm, with which he intended to extract not less than 88% of oil from olives. But the above plant did not pass the practical tests and was therefore abandoned.

In 1955 A. Corteggiani (14) proposed a vertical centrifuge for the extraction of the oil from olives. But also this centrifugal extractor was not able to achieve acceptable oil outputs.

In 1960 the Florentine Veraci Company (19) constructed an extracting centrifuge, which automatically discharged the solid sediments. It was called "Primolia", which at first stirred up a lot of interest, but it was then, also dropped, as the previous ones.

Almost in the same year the Westfalia-Enfida Company (7-8) constructed the "Microleo" process(18), based on the centrifugation of the olive pastes, previously stoned and treated with sodium chloride, after dilution with water. The results were similarly unsatisfactory.

In 1965, after a sixty year period of research, the solution to the problem was finally found, thanks to the Alfa-Laval Company which constructed the "Centriolive plant" adopted by the olive oil industry, even at present day. This plant extracts the olive oil by means of the three-phase "De-Sludger" centrifuge (with horizontal axle), which separates the following physical components from the olive pastes: oil, water and husk.

Later in 1971, the Italian Pieralisi Company produced a similar centrifugal plant, called S.C.. In the same year the centrifugal "Novoil" plant with " Flotweg " extractor, was also constructed by the Rapanelli Company. This types of continuous plant were then manufactured by other companies. These centrifugal extractors are today not sufficiently diffused for the industrial processing of olives. In Italy only 30% of the total plants are operative, even if they process more than 50% of olives produced, being as they are very efficient machines.

They perform a continuous oil extraction (2-4), are characterized by elevated automation (11), are less bulky (for which the costs for the construction of the working rooms are lower - this circumstance counterbalances their higher plant costs), they require a lot electric energy, as well as fuel and water, but the labour costs employed, are largely lower and furthermore they thorougly avoid the use of the filtering diaphrams, which involve an enormous expenditure. They consequently allow the obtainment of a higher profit, corresponding to more than 500 liras per quintal of olives processed (13).

They produce lower oil yields, which, however, in some cases, result comparable with ones of the classic system (15); furthermore they produce (20-25) a very humid husk (the moisture percentage of the solid by-product is, in fact, frequently about twice higher in respect to the reference system).

Finally (29-35), the oil is slightly less acid, richer in colouring pigments, not so rich in iron (being as the centrifugal plants are constructed in stainless steel), poorer in natural antioxidants, i.e. phenol constituents (because of the washing away action determined by the dilution water of the pastes). These phenolic substances, as known, not only protect the oil from oxidations, but also influence the flavour, which, in this way, results as being milder in the above oils. However, because the centrifuging system reduces the working time and consequently avoids an excessive storage period of olives, the oils obtained are frequently of better quality (41-43).

The problem of the washing away of the oil did not allow a very large diffusion or adoption of the continuous plants. For these reasons, research continued in order to solve the problem in question. The relative solution was found in 1992 when oil industry firms constructed the two-phase "decanters", which were able to centrifuge the oily paste without to diluting it with water. These "decanters" produced minimum amounts of liquid effluent since the vegetation water is not separated from the husk, consequently resulting as being rich in moisture. The previous three-phase "decanters" may be changed to two phases by means of simple adjustments performed by the crusher. The time required to do this is about half an hour.

The innovating "decanters" will give the oil-press the characteristics of a modern and more efficient industry, avoiding the problems of the old "trappeto".

As this topic is very important and related to, above-all, the improvement of the oil quality, in 1992 industrial essays of olive oil extraction were carried out in order to compare the technological results obtained by the new and old centrifuges. The quantitative results are here referred, whereas the experimental data concerning the analytical and qualitative profile of the two oil types will be given in a subsequent report. This subdivision has appeared inevitable because of the quantity of great figures obtained.

NMR analysis were also carried out on the oil samples and in addition they were pyrolised to achieve the mass spectra, which were statistically processed, applying conventional methods of multivariate analysis (PCA, CVA, PCCV) and neural networks (ANN, KANN and others).

2. EXPERIMENTAL

To carry out the research, three olive varieties (Leccino, Dritta and Coratina) were processed. Their composition and ripening index are given in tab.I. Their percentage content of oil, water and solids are visualized also by a graph (fig. 1). For each variety q 18 of olives were processed (homogenous lot), of which q 9 by two-phase centrifuge and q 9 by three-phase one.

Table I
Ripening index. Composition and characteristics of the olives - Other parameters.

VARIETY / DETERMINATIONS	CORATINA	NEBBIO	GROSSA DI CASSANO
Removal strength from tree (9)	499.0	566.8	577.5
Mechanical harvesting outputs (%)	93.0	73.0	89.0
Leaves (%)	7.3	16.5	9.2
Ripening index	1.5	4.3	5.8
P/S Ratio	3.6	4.7	4.1
Number of olives per Kg	502.0	638.0	440.0
Weight of 100 Olives	197.7	212.0	228.1
Mean diameter of the drupes	1.3	1.3	1.4
Moisture (%)	49 .4	44.4	45.7
Oil (%)	19.1	24.7	22.3
Solids (%)	31.5	30.9	32.0

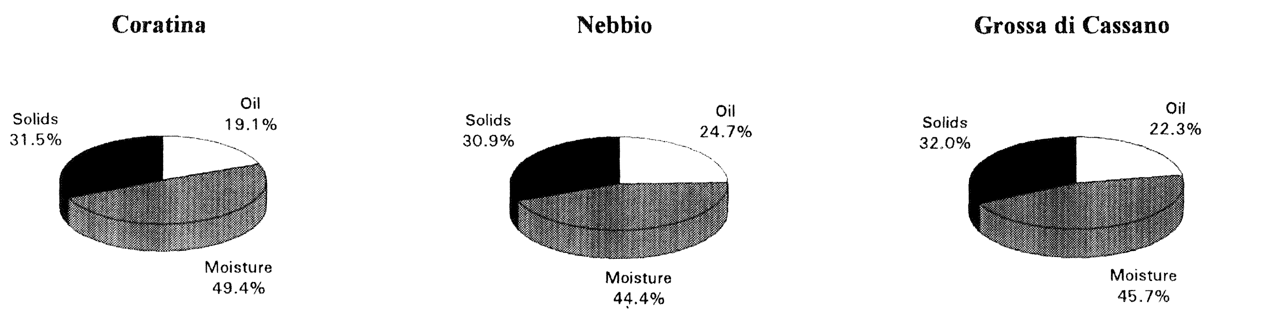

Fig. 1
Composition of the olive varieties processed. (%)

For each test, three repetitions using q 3 of olives were carried out. The extraction of olive oil was put into practice adopting the same industrial processing cycle and the same operating conditions applied in previous works (36-37). The steps of the two technological processes were the following:

- removal of leaves from olive lots;
- milling of drupes by a mobile hammer crusher. The grating holes had a diameter of mm6;
- malaxation of paste for 60' at 28°C;
- fluidification of oily paste with water(400 l/h) heated at 28°C when three-phase " decanter " was used. The hot water was no added to the paste centrifuged by two-phase "decanter". It was employed a Rapanelli-horizontal centrifuge, 400-S type, with which, by using specific head plates, was possible to process the olives according to a two or three-phase cycle. Plates used in the new "decanter" version lead to produce oil, husk and low quantity of vegetation water. This effluent could be considered as being the water in excess contained in the drupes processed;
- quantity of paste centrifuged per hour 6 q;
- separation of liquid obtained into oil and water by means of an automated discharge vertical centrifuge. During the experiments the samples to be analyzed (of olives, husk and vegetation waters) were taken. The methods of sampling and analysis were mostly the same ones adopted in the above indicated works.

3. RESULTS

The oil outputs achieved by the new "decanter" resulted, in average, comparable (and at times even higher) with the ones obtained by the previous centrifuge type (see tables II, III, IV and fig. 2). The oil percentages found on the husk (fig. 3), however, resulted higher (bot % humid base and % dry base). This is so because, as pointed out in the introduction, the vegetation water - which contained high oil amounts (fig. 4) - was almost entirely not separated from the solid by-product. In fact the liquid effluent quantity produced, corresponded approximately to 10 Kg per q of olives processed, while the reference centrifuge gave about 90 kg of waste-water water. The concentration of the former outflow was higher because it was not diluted by the processing water.

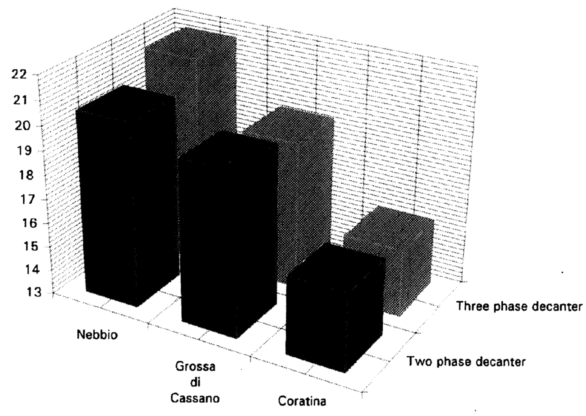

Fig. 2
Extraction outputs (%)

Table II
Extraction outputs and chemical characteristics of the by-products. CORATINA variety.

	OLIVES			HUSK			EFFLUENT		
Test n°	Lot Kg	Oil Kg	Output %	Moisture %	Oil % humid base	Oil % dry base	Dry residue % (m/v)	Oil g/l	Oil % s.s.
				TWO PHASE DECANTER					
1	300	39.1	13.0	64.5	3.29	9.27	9.4	6.96	7.37
2	300	45.8	15.3	64.4	2.94	8.26	10.4	9.34	8.98
3	300	52.3	17.4	53.2	3.38	7.22	11.0	14.64	13.36
Washing	-	8.5	-	-	-	-	-	-	-
Means	**300**	**48.6**	**16.2**	**60.7**	**3.20**	**8.25**	**10.3**	**10.31**	**9.90**
				THREE PHASE DECANTER					
4	300	32.3	10.8	48.1	2.18	4.20	5.7	3.68	6.47
5	300	52.7	17.6	49.1	2.44	4.79	6.3	4.08	6.44
6	300	48.4	16.1	50.5	2.67	5.39	7.4	6.58	8.92
Washing	-	8.5	-	-	-	-	-	-	-
Means	**300**	**47.3**	**15.8**	**49.2**	**2.43**	**4.79**	**6.5**	**4.78**	**7.28**

Table III
Extraction outputs and chemical characteristics of the by-products. NEBBIO variety.

	OLIVES			HUSK			EFFLUENT		
Test n°	**Lot Kg**	**Oil Kg**	**Output %**	**Moisture %**	**Oil % humid base**	**Oil % dry base**	**Dry residue % (m/v)**	**Oil g/l**	**Oil % s.s.**
				TWO PHASE DECANTER					
7	250	36.3	14.5	56.2	2.72	6.21	12.0	9.70	8.10
8	250	51.7	20.7	55.2	3.75	8.37	10.8	14.14	13.09
9	250	55.5	22.2	54.4	4.00	8.77	4.9	22.32	45.18
Washing	-	11.0	-	-	-	-	-	-	-
Means	**250**	**51.5**	**20.6**	**55.3**	**3.49**	**7.78**	**9.2**	**15.39**	**22.12**
				THREE PHASE DECANTER					
10	250	39.9	16.0	49.9	2.99	5.97	6.8	3.50	5.13
11	250	58.9	23.6	52.6	3.17	6.69	8.2	5.58	6.82
12	250	55.5	22.2	51.9	3.18	6.61	8.5	6.88	8.09
Washing	-	7.5	-	-	-	-	-	-	-
Means	**250**	**53.9**	**21.6**	**51.5**	**3.11**	**6.42**	**7.8**	**5.32**	**6.68**

Table IV
Extraction outputs and chemical characteristics of the by-products. GROSSA DI CASSANO variety.

	OLIVES			HUSK			EFFLUENT		
Test n°	**Lot Kg**	**Oil Kg**	**Output %**	**Moisture %**	**Oil % humid base**	**Oil % dry base**	**Dry residue % (m/v)**	**Oil g/l**	**Oil % s.s.**
				TWO PHASE DECANTER					
13	300	49.4	16.5	58.6	2.72	6.57	11.3	9.89	11.18
14	300	60.5	20.2	68.7	2.95	9.42	12.6	10.15	12.79
15	300	54.0	18.0	56.5	2.57	5.91	12.7	9.05	11.49
Washing	-	13.2	-	-	-	-	-	-	-
Means	**300**	**59.0**	**19.7**	**61.3**	**2.75**	**7.30**	**12.2**	**9.70**	**11.82**
				THREE PHASE DECANTER					
16	300	42.3	14.1	48.9	2.10	4.11	6.2	5.16	3.20
17	300	58.8	19.6	52.8	2.34	4.96	8.3	6.42	5.32
18	300	59.7	19.9	52.7	2.25	4.76	7.5	6.08	4.56
Washing	-	10.7	-	-	-	-	-	-	-
Means	**300**	**57.2**	**19.1**	**51.5**	**2.23**	**4.61**	**7.3**	**5.89**	**4.36**

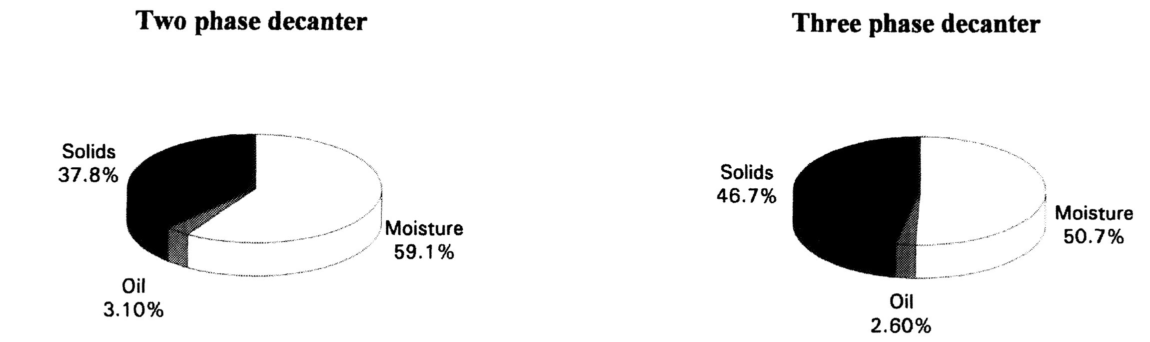

Fig.3
Composition (%) of the solid by-product (great mean)

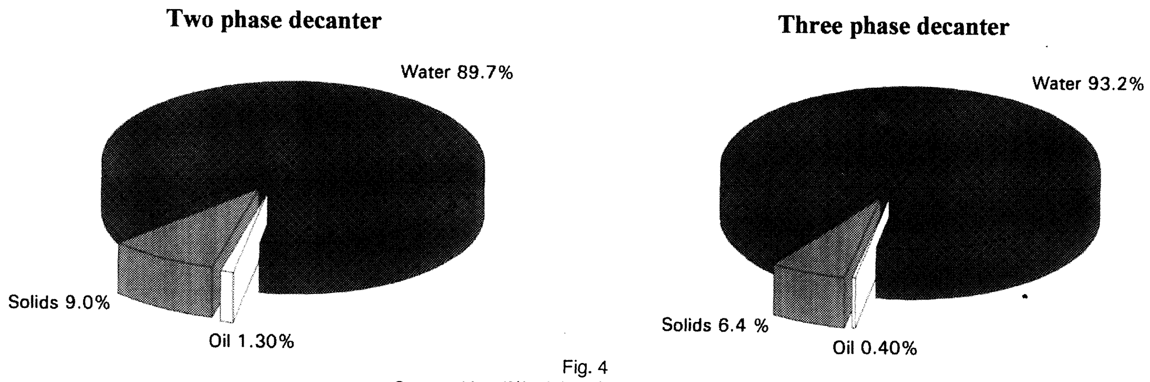

Fig. 4
Composition (%) of the effluent (general mean)

On the other hand, as was pointed out more than once, the husk amount resulted as being higher, because the olive cake also absorbed the vegetation water matter. This circumstance can also be relatively linked to the lower absolute pulp particles amount, lost in the effluent, since the olive pastes were not fluidified with hot water.

The higher dry pulp percentage in the husk -which was to be attributed mainly to the dry residue from the incorporated vegetation water- can be assumed by the data given in tab. V and the graph drawn in fig. 5.

The elevated moisture percentage of the virgin olive husk (55-60%) made, the industrial recovery of the residual oil from this by-product, difficult, hence some research is being carried out to verify the possibility of its agricultural employment as a fertilizer of land, eventually in mixture with other by-products, residues or wastes of the agrarian industries, and with chemical fertilizers.

Because of its higher concentration (i.e. lower ratio between liquid phase and solid one) the effluent was not only richer in fat, but also in phenols (fig. 6), although the paste fluidification water (added only when the reference centrifuge was used), in part, took away these substances from the oil and husk. Furthermore, the waste water showed higher COD, turbidity and dry residue values (tab.VI, fig. 7 and fig. 8).

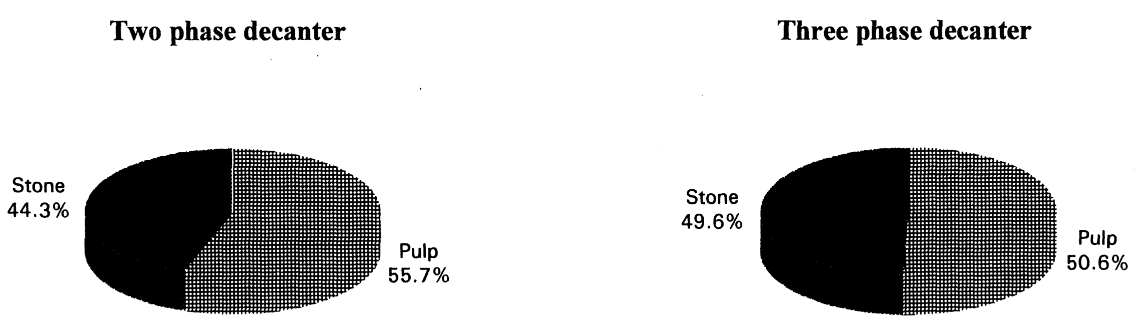

Fig. 5
Pulp content of the husk (mean general values, % dry base)

Table V
Physical composition of the husk and stone fragment granulometry. Average figure as % dry matter

DETERMINATIONS \ VARIETY	CORATINA		NEBBIO		GROSSA DI CASSANO	
	2 Phase dec.	3 Phase dec.	2 Phase dec.	3 Phase dec.	2 Phase dec.	3 Phase dec.
Skin %	2.9	5.4	5.2	4.1	6	4.9
Fine fraction ø <1 mm %	41.7	36.9	48.3	48.8	55.1	51.6
Stone fragments ø >3 mm %	9.3	13	5.7	5.1	3.5	3.4
Stone fragments ø 2-3 mm %	30.1	31	26.3	26.1	18.2	20.5
Stone fragments ø 1-2 mm %	15	12.9	13.1	15	14.7	17.9
Stone fragments ø<1 mm %	1	0.8	1.4	0.9	2.5	1.7
FSf/CSf ratio	5	3.4	7.2	8.2	10.1	11.8
Pomace P/S ratio %	80.5	73.3	115.1	113.3	157.1	129.9
Pulp%	44.6	42.3	53.5	52.9	61.1	56.5
Stone %	55.4	57.7	46.5	47.1	38.9	43.5

Table VI
Other analytical parameters determined on the vegetation waters. Means values

VARIETY	DECANTER	COD g/l	Phenols (caf.acid) g/l	o-Diphenols (caf.acid.) g/l	Turbidity NTU
Coratina	2 phase	175.4	7.2	2.8	1470
Coratina	3 phase	138.5	4.4	1.8	1077
Nebbio	2 phase	193.8	6.4	2.5	630
Nebbio	3 phase	156.9	4.1	1.8	280
Grossa di Cassano	2 phase	212.3	6.9	3.2	3140
Grossa di Cassano	3 phase	187.7	4.5	2.4	277

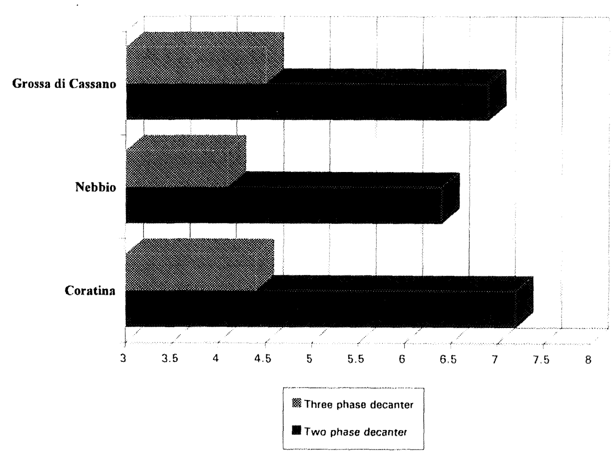

Fig. 6
Phenols content of the vegetation water (g/l)

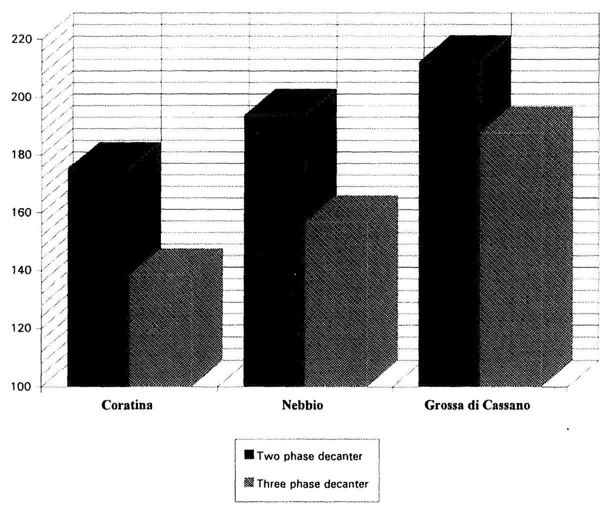

Fig. 7
COD of the vegetation water (g/l)

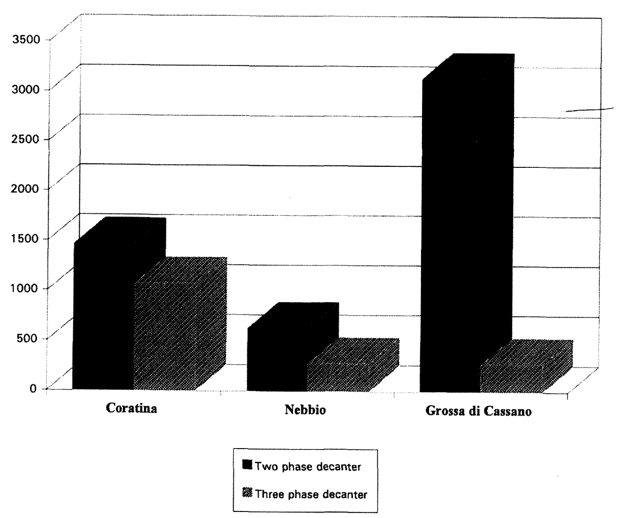

Fig. 8
Turbidity of the vegetation water (NTU)

To summarize, the two-phase decanter permitted a reduction of the costs for processing the olives, because:

- it did not use, or used minimum amounts of hot water to dilute the pastes to be centrifuged. One is to consider that in Italy, prior to such technological innovation, 800 thousand cubic meters of drinkable water were consumed for the olive oil extraction by the centrifugal system;
- consequently the vegetation water amount produced (as above underlined) was very low, for which the costs for its purification were almost avoided. With regard to this, it was to be pointed out that in Italy a hypothetical replacement of all three-phase "decanters" with the two-phase ones permitted a reduction of the processing costs, avoiding (or almost) the expenditures for the filtering of the oil-mill waste water, amounting to around 40 milliard liras, if we consider that the cost to purify one cubic meter of vegetation water was equal to about 50 thousand italian liras;
- the electric energy consumption, to warm processing water, was greatly reduced;
- It was possible to increase the amount of olive processed per hour, being as the use of the processing water was avoided, the oily mass to centrifugated was lower.

Furthermore to be considered, was the great economic advantage related to the higher qualitative level of the oils produced. These oils in fact (as will clearly be illustrated in the second part of the present work) pointed out better chemical and physical characteristics, obtained a higher sensorial score and were also characterized by a longer shelf-life, higher content of aromatic volatile substances and a greater concentration of natural antioxidants.

The only problem to be solved was the elevated moisture percentage of the husk, which almost compromised its traditional industrial recycling, for which it was necessary to find alternative solutions for the use of this by-product. We will verify the possibility of its employment as organic fertilizer of the lands.

4. CONCLUSIONS

In comparison to a conventional one, the two-phase or ecological "decanter" (so called because it produces only the oil and husk and not also the vegetation water) frequently allows the achievement of higher oil yields. It was able to centrifuge the oily pastes which were not diluted by hot water, when fresh olives were processed (i.e. with a moisture degree of about 50%). When, instead, the olives contained rather low humidity percentages, it was necessary to dilute the olive pastes with warm water amounts inversely proportional to their moisture level. In any case, such hot water quantities were always very low. The pasty mass water was made up, almost a hundred per cent, from the drupes.

The implications of the new centrifugal system used were two:

1) the non production (or almost) of the waste water, that solved at best the enormous problems connected to its filtering;
2) the production of oils not impoverished of poliphenols, as were instead the ones produced by the previous centrifugal system. The latter oils were washed away by the hot water added to the olive pastes and therefore their quality could not compete with that of the pressing or percolating oils, notwithstanding the validity and the superiority (as regards certain profiles) of the continuous system. That is why a large diffusion of the new centrifuging "decanters" was to be expected.

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