Economics of Energy Use in Various Solvent Extraction Processes

G. JURISTOWSZKY, Agroindustria, JNA 87, 21000 Novi Sad, Yugoslavia

ABSTRACT

Energy consumption such as steam and electricity for processing various oilseeds, particularly sunflower and rapeseed, is compared for three different processes—conventional prepressing and solvent extraction, direct solvent extraction, and cold prepressing of whole seed and solvent extraction. Besides emphasizing energy, the talk discusses aspects of quality and economics of edible oil production.

Five processes have been used to recover oil from high oil seeds: hydraulic, expeller, classical combined process of thermal processing and solvent extraction, process of direct solvent extraction, and combined process of the cold prepressing and solvent extraction.

The hydraulic process with discontinuous expellers is old-fashioned, operationally intensive technology. The capacities of the equipment are limited to several dozens of tons per day. Today it is used in exceptional, special cases only, such as processing of dried pumpkin kernels in order to produce the very desirable pumpkin oil for salads in some regions of Italy, Austraia and Yugoslavia.

Due to the low capacities, old-fashioned technology, intensive operating conditions, relatively high investments per unit capacity, and the high oil residue in the cake, this process is not recommended for daily processing capacities of over 50 tons of raw material.

With the expeller process, oil is produced by subjecting the prepared seed to the high pressure in one or two stages mechanically. Therefore, this process has been called mechanical extraction as well. The process is continuous in screw expellers, and at very high pressures. The high pressure requires heavy-duty expellers with unit capacities at present limited to ca. 50 tons of processed raw material per day. Expeller processing is most practical in plants that handle less than ca. 100 ton/day.

For plants that process more than ca. 100 ton/day, many factors need to be considered in choosing the right process. These factors would include suitability of the process for the oilseed being handled, power requirements, safety measures needed and product quality desired etc.

Most manufacturers of the oil processing equipment have special designs for each type of process. The three basic technological processes that are used for higher volume plants can be presented by the schemes of operations in Table I.

TABLE I

Classical process	Direct extraction	Process of cold prepressing and extraction
Crushing	Crushing	
Milling	Flaking	
Cooking	Granulation	
Prepressing		Prepressing
Solvent extraction	Solvent extraction	Solvent extraction
Desolventizing	Desolventizing	Desolventizing

The classical process requires the largest number of operations, and that infers the highest investment in the appropriate equipment.

The cold prepressing and extraction process includes equipment for prepressing, extraction and desolvantizing that is also the largest part of the costs of the equipment used in the classical process. The price of the equipment with this process is lower than that with the classical process due to elimination of equipment for crushing, milling and cooking. However, the expeller for this process is more expensive than the corresponding expellers for the classical process.

The lowest cost of equipment per unit of capacity is for the direct extraction process, due to elimination of prepressing operation. In estimating the contributions of the above different technological processes to the price of the equipment, it has to be made clear that the difference in cost is attributable to the process and not due to many of the other possible factors.

These cost differences, of course, cannot anticipate the differences in prices of the equipment that will appear in the quotations of the different equipment manufacturers. These differences can be substantial, as is known from our experience, even when the manufacturers quote the equipment of the same capacity, based on the same technology, even on the same licence.

Cost bids are based on certain quality of the material, workmanship, the thickness of the constructional sheet metal, heavy-duty construction, the experience of the manufacturers and their organization level, the interest of the supplier to obtain the business, their interest in having the references in the market, the rate of foreign exchange as well as the stimulation of export in the country of origin, and other elements that are not the result of the technological differences of the process. All these factors will be individually estimated at analyzing the quotations.

Excluding the aforementioned nontechnological influences on the price of the equipment, and for the capacity of processing 300 tons of raw material per day, being proposed as the optimum at the meeting of oil experts in Madrid organized by UNIDO, we have found good agreement of investment costs in designing several factories of crude oil in Yugoslavia with the indices given in Table II.

In addition to investment costs, operating costs must be considered in the choice of a process. Only those items in which the essential differences appear with the greater influence to the costs of production, are the result of differences in technology. For instance, the major process variables influencing operating costs are consumption of hexane, residual oil in meal and power and steam consumption.

The loss of hexane is not so much influenced by the technological process as it is by the quantity of material being extracted and by the desolventizing and solvent recovery systems used.

Consider a factory that processes 300 tons of raw material per day during 280 days a year, i.e., totaling ca. 80-85,000 ton/year (50% sunflower seed, 35% rapeseed and 15% soybean). With 0.3% loss of hexane based on input

TABLE II

	Classical process	Direct extraction	Cold prepressing with extraction
Investments into basic technological equipment for prepressing and extraction, i.e., with direct extraction with preparation	100	75	93
Investments in erected equipment and all kinds of installations	100	82	95
Total investments in construction of the factory for crude oil	100	85	94

material, the average consumption of hexane per ton of processed raw material amounts to (a) classical process: 1.842 kg; (b) direct extraction: 2.750 kg; and (c) cold pressing with extraction: 1.824 kg.

The residual oil in meal reduces the output of crude oil, and increases the output of meal. There is no essential difference in residual oil in meal between the classical process and the direct extraction process. However, with good preparation of the material for the extraction by the cold prepressing process, the average oil content in meal is ca. 0.3% or lower than in meal processed in the classical process or in the direct extraction process.

This has been studied in tests by the Department for Oil Technology of the Food-biochemical Faculty in Zagreb. Their tests have shown the excellent breaking of the cells in cold pressing, improved porosity of the cake, faster extraction of oil and greater recovery of oil than in the classical process. This has been confirmed by plant results as shown in Table III:

The most important comparative item with regard to operating costs is power consumption. This consumption is given as the total for electric and thermal energy, expressed in kWh/ton of raw material, multiplying one kg of steam with 0.555 kWh. (See Table IV).

Comparative indices for power consumption in the three processes are given in Table V.

The splits between steam and electrical requirements are different for each process and are given in Table VI.

TABLE III

	Residual oil in meal (%)		
	Classical process	Direct extraction	Cold prepressing with extraction
Sunflower seed	1.0	1.0	0.7
Rapeseed	1.4	1.4	1.2
Soybean	0.8	0.8	0.65

TABLE V

Process	Index of power consumption
Classical process	64
Direct extraction	100
Process of cold prepressing with extraction	49

TABLE VI

	Percentage of total power	
	Electric (%)	Steam (%)
Classical process	47	53
Direct extraction	32	68
Process of cold prepressing and extraction	69	31

These data, of course, can be accepted in outline only. In each specific case, it is necessary to consider energy consumption depending on the design of the process and the capacity.

The lowest power consumption with the process of cold processing with extraction is the result of elimination of the thermal preparation of the material by prepressing, and it is replaced by an increased efficiency due to breaking of the cells by prepressing. The highest power consumption in the direct extraction process results from the fact that ca. 80% of the total oil of high oil seeds is removed by pressing and only 20% by solvent extraction. With direct extraction, the total quantity of the produced oil is obtained as extracted oil. This causes the high consumption of thermal energy needed to distill solvent from the oil and meal.

TABLE IV

	Power consumption (kWh/t)		
Operation	Classical process	Direct extraction	Cold prepressing and extraction
Mechanical preparation	10	20	–
Cooking	65	90	–
Prepressing	15	–	35
Solvent extraction	1	1	1
Desolventizing	50	150	50
Transport and other costs	50	40	60
Total	191	301	146

Analysis of the different investment costs and the direct costs of production, enable determination of the economic index of the financial suitability of the three processes, as they influence profitability of the future venture.

In the above example of a plant to process 300 tons of combined average sunflower seed, rapeseed and soybean, and according to the market prices in Yugoslavia, the calculated processing costs of one ton of raw material is as given in Table VII.

As can be seen in Table VII, the lower power and investment costs of the prepress/extraction process provide considerable economic advantage, i.e., on 80,000 tons it is US $410,000 over the direct extraction and US $535,000 over the classical process.

Of the processes that have not yet been promoted in industry is the extraction of oil by supercritical carbon dioxide under high pressures. Even at the present stage of development and testing, it seems as though this can be developed into a commercial process. In areas where energy costs are high and are likely to increase faster than general prices, special concern should be paid to the lower power consuming processes.

The qualities of oil and meal obtained by the different processes deserve consideration. Crude oil and meal have different qualities depending on the process used. These quality differences are reflected in the crude oil in the degree of oxidative stability, the organoleptic properties and the free fatty acids. The processed meals vary in the degree of digestability of proteins. The direct extraction gives without doubt the best quality of crude oil and mill, with characteristics closest to the natural state of oil and proteins in seed.

For comparison of quality of crude oil produced by the classical process and by the process of the cold prepressing, the indices given in Table VIII can be indicative.

American researchers at the USDA have stated that, in the case of groundnut processing, the content of soluble proteins in meal after the direct extraction has been 85% compared to only 60% by classical processing. Digestibility of proteins is of great concern to the animal feed industry.

It is understandable that the lighter color and the lower degree of oxidation of crude oil with lower FFA obtained will reduce the costs of refining the oil and probably make for a better quality finished refined oil.

TABLE VII

Kind of costs	Costs (US$) of raw material/ton		
	Classical process	Direct extraction	Cold prepressing and extraction
Depreciation	18.80	15.18	17.49
Installments	26.85	21.68	24.99
Hexane	1.24	1.85	1.23
Power	11.46	18.06	8.76
Oil in meal	3.57	3.55	2.74
Total	61.92	60.32	55.21
Index	112	109	100

TABLE VIII

Index of quality of oil	Classical process	Process with cold prepressing
Anisidine value	1.4	1.1
Peroxide value	2.1	1.3
Totox no.	5.6	3.7
Color/Lovibond/		
green	3.0	3.0
red	3.1	2.7
blue	1.0	0.2
Chlorophyl, ppm	11.7	5.7
Extinction/258 mm/	1.7	1.5