Analysis of electronic systems for control of crops pretreatment processes in vegetable oil extraction

Seher Kadirova

Abstract: *The paper presents a comparison of oil extraction technologies and classifies the electronic systems for control. Different types of preliminary crops processing technologies are compared – pretreatment for solvent extraction, for supercritical fluid extraction, thermal-moisture treatment and subsequent pressing etc. The electronic systems for control and maintenance of the processes are analyzed.*

Key words: *oil extraction, technologies, crops pretreatment, control, system*

INTRODUCTION

The production of oil is a widespread and actual problem. There are different types of oil producing technologies, which require specific meal processing and control of parameters for achieving product with high quality and quantity. One of the most important parameters is the preliminary treatment of the material before mechanical pressing or solvent extraction. The purpose of pretreatment is to break the seed walls and release the oil for extraction. The most often used technologies for oil production are: solvent extraction, supercritical fluid extraction, screw pressing, enzyme-aided aqueous extraction etc.

DESCRIPTION OF OIL EXTRACTION TECHNOLOGIES

Solvent extraction: The effectiveness and efficiency of extraction depend on many factors, including the solvent used, solid preparation, extraction temperature, modes of operation, and equipment. The choice of solvent for extraction is largely determined by the solubility characteristics of the constituent of concern and the solid[2].

Typical solvent extraction processes involve the four basic steps of preparation, extraction, solvent recovery from the extracted oil, and desolventizing or flash desolventizing of the de-oiled seed meal. Conventional preparation generally comprises the steps of cleaning to remove foreign material; drying to loosen hulls; additional cleaning; cracking to break the oilseed into pieces properly sized for dehulling and flaking; optional dehulling; conditioning to adjust temperature to approximately 70° C and water content to less than about 11 percent b.w.; flaking; and optionally converting flakes into collets. Flake thickness generally ranges from about 0.2 mm to about 0.5 mm. In the optional colleting step, expanders are used to transform flakes into sponge-like extrudates termed collets[3].

The pretreatment given to the oil-bearing solid frequently plays a very important role in the efficiency of the extraction process. In many instances of extraction, small particles of the soluble material are completely surrounded by a matrix of insoluble materials. The extraction process must find a suitable compromise between the increased extraction rate obtained by reducing the particle size and increased difficulty in separating the small solid particles from the liquid solvent. Pretreatment techniques can be used to disrupt cell walls chemically or thermally. Seed preparation includes heat and moisture adjustment to facilitate cell disruption and solvent penetration[12].

For oil extraction, nonpolar solvents are usually used, as triglyceride-based oils are typically miscible with these solvents. The most common solvents in solvent extraction of oil are light paraffinic fractions. Both hexane (bp 66-69˚C) and heptane (bp89-98˚C) mixtures are widely used, sometimes cyclic hydrocarbons, such as cyclohectane (bp 71-85˚C) are also used. While the solvents are efficient in oil extraction, the major disadvantage to there use is there flammability[11]. Because of the safety and environmental issues associated with the use of hexane, the construction and operational costs of hexane extraction facilities are high[8].

Currently, hexane is the solvent prevalently used because it satisfies many of the requirements of an ideal solvent. Other solvents or solvent mixtures have been considered in recent years because hexane is volatile, ignites easily, and may pose substantial health risks when inhaled[8]. Although hexane gives a high yield, the process requires high capital investment. Moreover, it can be emitted to the atmosphere during the extraction and recovery steps, where it can react with other pollutants to produce ozone and photochemical oxidants, which can adversely affect the environment[4].

Typically ratios of 1-1.25 weights of solvent per weight of prepared oilseed material are used and extraction is conducted at about 8-11°C lower than the boiling point of the solvent[12]. The solvent extaction is done by passing the solvent through the material. The solvent is distilled off, leaving the oil retained in a tank[2].

Supercritical fluid extraction: Supercritical fluids can be used to extract analytes from samples. The main advantages of there using for extractions is that they are inexpensive, contaminant free, and less costly to dispose safely than organic solvents[7].

The most popular supercritical fluid extraction solvent is carbon dioxide (CO2), sometimes modified by co-solvents such as ethanol or methanol. Tryglycerides, cholesterol, waxes, and free fatty acids are quite soluble in supercritical CO2. CO2 has the additional advantage of being nonflammable and less toxic than most organic solvents[7].

Supercritical fluids can have solvating powers similar to organic solvents, but with higher diffusivities, lower viscosity, and lower surface tension. The solvating power can be adjusted by changing the pressure or temperature, or by adding modifiers to the supercritical fluid. A common modifier is methanol (typically 1-10%) which increases the polarity of supercritical CO2. Extraction conditions for supercritical CO2 are above the critical temperature of 31°C and critical pressure of 74 bars. A supercritical fluid can be defined as a form of matter in which the liquid and gaseous phases are indistinguishable[7]. The size of the particles must be with diameter less than about 5 micrometers[9].

Critical temperature and pressure, compressibility, density, heat capacity, dielectric constant, viscosity, diffusivity, and thermal conductivity are important properties, which characterized supercritical extraction process. When a substance is compressed and heated to its critical point it enters a phase referred to as “supercritical phase”. The matter that is in the supercritical region is called a supercritical fluid (SCF). Temperature, pressure, and molar volume of a substance at the critical point are collectively referred to as critical constants. Process modeling and operating conditions, as well as economic feasibility for an extraction process, require information on phase equilibrium between the solute and solvent involved[12].

Enzyme-aided aqueous extraction: The aqueous extraction process has been practically applied to extract oil from several oilseed and fruits. In comparison with solvent extraction, the enzyme-aided process operates under milder conditions, such as lower temperature. This process has certain limitations, the chief ones being lower efficiency of oil extraction, provision for de-emulsification, enzyme costs, and the treatment of aqueous effluent[4].

The basic principle is to digest the cell walls of oil containing materials with suitable enzymes to extract oil, protein, and other compounds present in intracellular vacuoles, under milder processing conditions than Aqueous extraction process. This method involves heating seeds, grinding with or without water, and boiling with water to liberate the oil, which appears on the surface[4].

Screw pressing: Mechanical pressing is the most popular method of oil separation from vegetable oilseeds in the world[1]. The main reason for popularity of mechanical oil expellers is that these equipments are simple and sturdy in construction, can easily be maintained and operated, can be adapted quickly for processing of different kinds of oilseeds, and the oil expulsion process is continuous with product obtained within a few minutes of start of the processing operation. The safety and simplicity of the whole process is advantageous over the more efficient solvent extraction equipment. The mechanical screw presses are relatively inefficient, leaving about 8±14% of the available oil in the cake[10].

The preparation for screw pressing consists of cleaning, grinding, thermal-moisture treatment, and screw pressing. Moisture content, duration and temperature of roasting are some of critical parameters influencing oil expression. Oil yields decrease steadily with increase in moisture content, therefore it can be said that the moisture content before pressing is the most significant factor.

The moisture content of flakes usually is in the 10-12% range. In “cooking” for full pressing they are dried to 5% moisture content to maximize oil recovery. Most cottonseed today is processed by flaking, passing through an expander and then solvent extraction[5].

ELECTRONIC SYSTEMS FOR OIL RECOVERY

An electronic system for oil extraction using solvents: The device shown in Figure 1 is a fully automatic machine for oil extraction. This is accomplished by the fully automatic control by computers and with a new running mode and a more logical mechanism. There are several absolute value coders that can measure the driven hub’s angle of rotation, an augmenter coder that can measure the rotation speed of the electrical motor and an oil gauge. In this system, a central processing unit, an input/output module and a liquid crystal display constitute the oil production process controller collects signals and then the device controls the machine, the beam and the pump system automatically. It can adjust the running speed of the ascending travel or the downgoing travel to fit to the rise of the hanger of the oil-well so that the efficiency of oil extraction will increase. The system has the advantages of a large load capacity, manual, automatic, or long-range communication administration, automatic alarm and so on. It also has the advantages of saving energy, high efficiency for oil extraction and long operational life span[6].

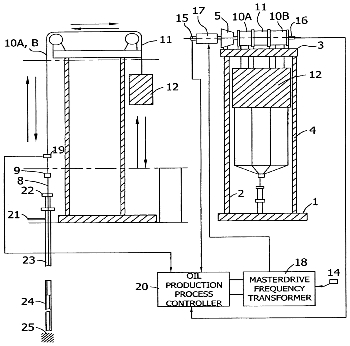

Figure 1: Electronic system of a fully automated machine for oil extraction

Electronic system for oil extraction using supercritical fluid: Figure 2 illustrats the flow of fluids, solutions and particles in the method. A carbon dioxide reservoir containing liquid CO2 is connected to a pump, through which it is pumped under conditions at which it becomes a supercritical fluid or near critical fluid, when it reaches the heated mixing tee. Aqueous solvent reservoir is connected to fluid pump, which is connected to the injection port. The solution of aqueous solvent from reservoir, and protein solution, with or without additives injected through injection port, is connected to mixing tee. Mixing tee preferably has a low dead volume, e.g., less than about 10 μl so than an intimate mixture of the supercritical CO2 and the aqueous solution may be formed therein. Mixing tee is equipped with pressure restrictor maintain back-pressure in mixing tee, and may be optionally equipped with heating coils to maintain supercritical temperature therein[9].

In operation, the liquid carbon dioxide is pumped by means of pump reservoir through pump and to the low volume (0.2 to 10 µl) mixing tee where it becomes a supercritical fluid, or a near critical fluid. The flow of carbon dioxide and aqueous solution are adjusted independently by means of valves. Flow rates can also be controlled by altering pumping conditions. The mixture in mixing tee expands downstream and forms aerosol comprising fine particles of the substance dissolved or suspended in the aqueous solution. The use of injection port allows equilibration of the system which is reached when the temperature of the drying tube is equilibrated as measured by a thermocouple and the flow rates of aqueous solution and carbon dioxide reach steady states.

When a sample injection valve is used, typical system parameters include: CO2 pressure 100 atm; CO2 flow rate 0.3 ml/min; aqueous flow rate 0.3 ml/min, using a 5 cm long fused silica restrictor with 50 µm inner diameter[9].

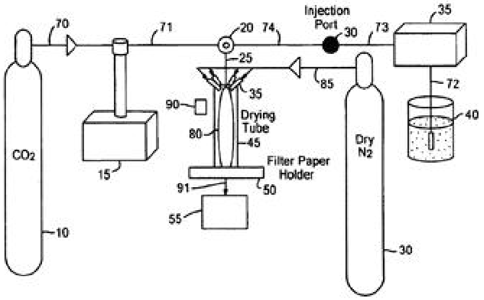

Figure 2: Electronic system for supercritical fluid extraction

Screw pressing system: As the oilseed fed through a regulated feeder enters into the feed section (Figure 3) of the primary section of the screw, it is conveyed to the ram section where it disintegrates into small particles, thereby exposing a larger surface area to the pressure application in the forthcoming primary plug section. The pressure in the primary plug section is generated due to restriction created by an intermediate choke. This creates axial and thereby radial compression on the disintegrated oilseeds, rupturing the cell-walls, and facilitating removal of oil from the oilseed. The extracted oil flows through slits provided in the barrel through shims in the primary plug section.

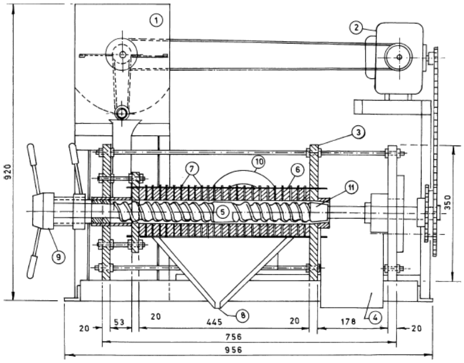

Figure 3: Semi-sectional view of the screw press (oil expeller)

Meanwhile, as oilseed is continuously fed through the feeder, the material in the primary plug section moves forward to the secondary section where it enters the ram section directly. In this section, it is subjected to a gradually increasing pressure, which remains however, lower than that in the preceding primary plug section. This provides an all-important breather to the material which then enters the secondary plug section and is compressed to the maximum pressure designed for the press before finally exiting from the expeller. This second compression is more effective since the clearance between the barrel and screw can be reduced considerably with the help of the end cone clearance. To accomplish this, the end part of the worm is of conical form. The backward movement of the worm (i.e. movement towards the feed hopper) increases the clearance and thereby reduces the pressure on oilseed present inside while its forward movement does it otherwise. Using this mechanism, a clearance in the range of 0.8±0.4 mm was attainable.

CONCLUSIONS AND FUTURE WORK

In conclusion it can be said that the fully automated electronic systems are effective, need less workers, have low levels of residual oil in the meal. The disadvantages are the high capital investment and the complexity of the process, the difficult control of the system and the parameters. While the solvents are efficient in oil extraction, the major disadvantage to there use is there flammability in low temperatures. The supercritical fluid extraction technology has more advantages than the solvent extraction, but the capital investments for the apparatus are high too. The complexity of the process can't be ignored as well. The level of residual oil in meal cake is higher in oil pressing technology, the equipments are simple and sturdy in construction, they can easily be maintained and operated, can be adapted quickly for processing of different kinds of oilseeds, and the oil expulsion process is continuous with product obtained within a few minutes of start of the processing operation. The safety and simplicity of the whole process is advantageous over the more different extraction processes.

REFERENCES

[1] Berk, Z., Technology of production of edible flours and protein products from soybeans, FAO agricultural services bulletin no. 97, 1992

[2] Britt, L., U. S. Patent WO2005086928, (2005)

[3] Copeland, D., G. Hoover, and W. Belcher, U.S. Patent 7,122,216 B2 (2006)

[4] Dunford, N., H. Dunford, Nutritionally enhanced edible oil and oilseed processing, AOCS Press, 2004, 314p.

[5] Kulp, K., and J. Ponte. Handbook of Cereal Science and Technology, Marcel Dekker, 2000, 790p.

[6] Lu, X., U.S. Patent 6,749,017 B1, (2004)

[7] Luthria, D, Oil extraction and analysis, AOCS Press, 2004, 282p.

[8] Moreau, R., D. Johnston, M. Powell, and K. Hicks, A comparison of commercial enzymes for the aqueous enzymatic extraction of corn oil from corn germ, JAOCS, vol. 81 (11) 2004, 1071-1075p.

[9] Siever, R., Sc. Sellers, and J. Carpenter, U.S. Patent 6,330,121 B1 (2003)

[10] Singh, J., and P. Bargale, Development of a small capacity double stage compression screw press for oil expression, Journal of food engineering 43 (2000) 75-82p.

[11] Singh, K., D. Wiesenborn, N. Kangas, and K. Tostenson, Characterization of Preparation Parameters for Improved Screw Pressing of Crambe Seed, Transactions of ASAE, 2002, 45(4):1029-1035p. (screw pressing)

[12] Tzia, C., and G. Liadakis. Extraction Optimization in Food Engineering, Marcel Dekker, 2003, 456p.

ABOUT THE AUTHOR

Seher Kadirova, Department of Electronics, University of Rousse, Phone: +359 82 888 516, E-mail: skadirova@ecs.ru.acad.bg.

Докладът е рецензиран.