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Gas-assisted oilseed pressing - Design of and tests with a novel high-pressure screw press

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Abstract

Vegetable oils like rape seed or soybean oil are produced industrially in large scale. Key process step is mechanical expression of the oil from the feed material, e.g. rape seed. A new process for enhanced pressing of oil-seeds was designed and realized in pilot scale. The novelty is the additional use of pressurized gasses in screw-pressing which can modify oil yield as well as oil and cake properties. Uniaxial gas-assisted pressing enhances oil yield significantly, but a pilot screw press with pressure housing did not so far.

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Keywords: Screw-press; Carbon dioxide; Oilseed; Gas assisted pressing; GAME

1. Introduction

Industrial screw-pressing of oil seeds to produce oils is a large scale and well-established process[1]. After mechanical or thermal pre-treatment the seeds are partly deoiled by application of mechanical forces. Technical options are cage presses with axial force only and for higher efficiencies single- and twin screw presses. Despite high mechanical forces the obtainable yield is limited and ways of enhancement are more than welcome. A newer idea is to use compressed gasses like Carbon Dioxide (CO_2) to shift material properties in a way favourable for higher yields. Scientific studies [2-6] with model systems in small scale have proven, that the additional application of CO_2 can alter the pressing process in a favourable way. These tests were performed using axial high pressure presses modified to operate with added compressed gasses. Figure 1 shows the principle such a set-up. The oil yield (which denotes the ratio of oil recovered during pressing and initial amount of oil in the seeds) increased from 27% to as much as 71% when using gas assistance with CO_2[2]. Reasons are the beneficial alteration of oil

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properties due to contact with compressed CO_2: CO_2 shows high solubility in vegetable oils and e.g. lowers their viscosity and interfacial tension significantly[7,8]. While the underlying physical effects have been depicted in the quoted literature, optimum parameters for industrial presses (temperature, pressure, phase state, metering, seed pre-treatment, residence time) have not been reported so far.

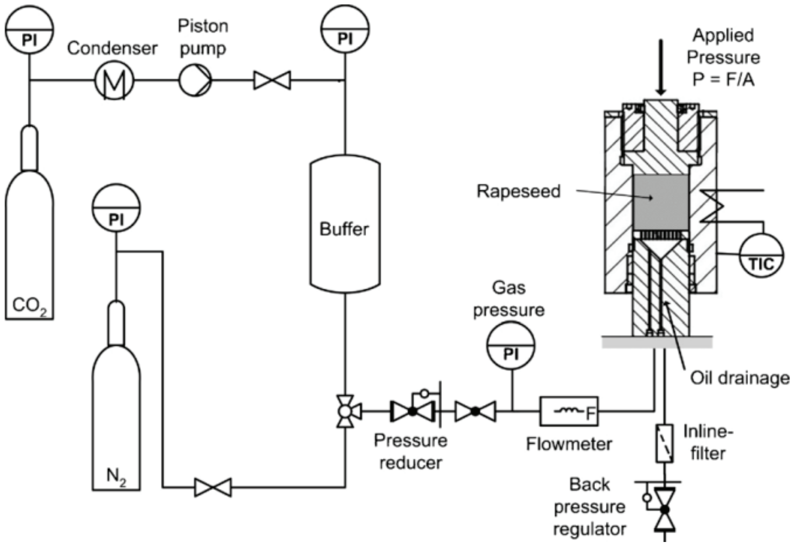


Fig. 1. High pressure Uniaxial Piston press for gas assisted pressing used by Voges, Eggers and Pietsch [2]

Uniaxial presses – also called hydraulic presses - are mainly in use for cocoa pressing, while most other oil seeds are pressed with continuous screw presses to obtain an economic throughput. The seeds are crushed, compacted and deoiled by continuous mechanical agitation and multiple squeezing inside the presses. Therefore the next step to transform the exciting findings form uniaxial gas –assisted pressing into industrial production technology is to design, realize and test a pilot screw press system with CO_2 injection. The challenge is to handle the high-pressure gas in a safe way. In figure 1 two general principles from literature are shown. Either the CO_2 enters the press through the worm shaft or through the pressing body. The first principle demands that drive momentum and the high-pressure gas supply have to come through the same shaft. In table 1 these and other principles of injection are listed. This work reports first findings of gas assisted pressing with a screw press, testing different ways of gas-injection.

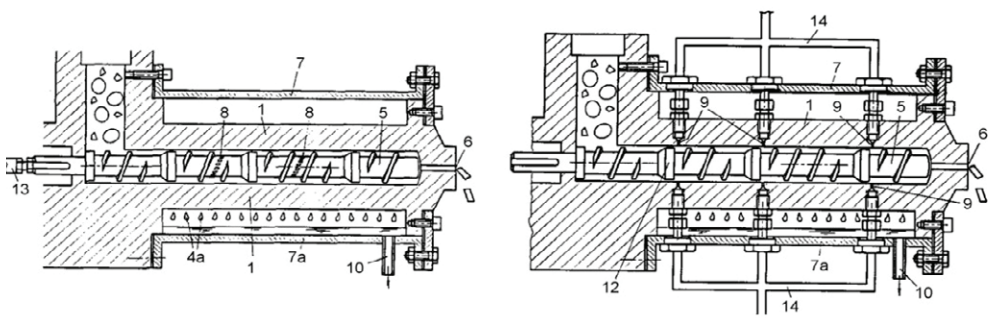
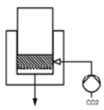
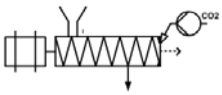
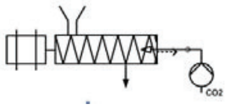
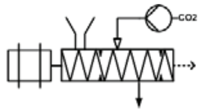
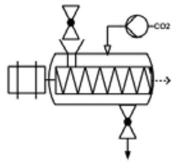


Fig. 2. Suggestions of design of CO2 injection with pressure-tight casing according to Foidl [9]

Left: gas supply via worm shaft, Right: gas supply via barrel, 1: pressing body, 4a: oil-gas mixture, 5: press screw/worm, 6: Discharge outlet, 7: casing, 7a: vat, 8+9: gas inlet, 10+11: gas/oil outlet, 12: choke, 13+14: CO2 inlet pipe.

Table 1. general overview on some methods to feed high-pressure CO2 to a press system

Injection type	**I)**	**II)**	**III)**	**IV)**	**V)**
	Uniaxial press	**CO2 into head**	**CO2 into screw**	**CO2 into cylinder**	**press inside pressure vessel**
					

Nomenclature

p	pressure [MPa]
T	temperature [°C]

2. Materials & Methods

A small scale single-screw press (type DD85 from company IGB, Germany) and Rape seed from Germany, (harvest 2010 fully untreated, 45.2% oil content, 7.1% water) was used for the investigation. While large scale presses use strainers and a series of “throttle rings” this lab-scale press holds only a single throttling step at the outlet of the residue (expeller), which is a certain drawback to this lab-technology as will be explained later on. At the outset the optimum press parameters for maximum yield at 65°C were determined. In the second step, the press was equipped with CO2 injections systems according to type II, III and V as shown in tab.1. Oil content of all solid samples was determined by Soxhlet extraction. The obtained crude liquid oil was weighed as is which seemed reasonable since sediments were negligible in all cases.

3. Results & Discussion

Regular pressing without CO2 injection was performed with various parameters to determine the setup and parameters for maximum oil yield. For simplification water content of the feed was not varied, although it is well known, that it takes significant influence. Temperature was stet to 65°C in order to mimic first stage industrial rape-seed pressing. Smaller nozzle sizes lead as expected to higher yields but also to the risk of blockages. Nozzle size of 6 mm was found as a practical optimum, other influences are depicted in fig. 3. After optimization the yield of the screw press is much higher than that of uniaxial pressing and even higher than uniaxial pressing with gas assistance.

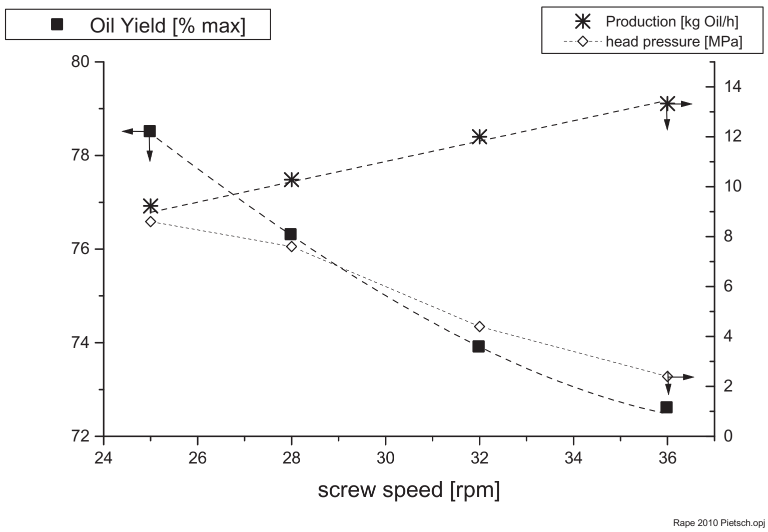


Fig 3. Results test-pressing of rape seed at 65°C, nozzle diameter 6 mm

Subsequently to optimization of the standard setup an injection system for CO_2 was designed and built by Eurotechnica GmbH. The available lab type press has limited wall thicknesses and therefore options to inject are limited. The first setup (fig. 4 left, type II) injects the CO_2 into the press-screw with an opening into the throttling zone. Connection to the CO_2-tubing is realised with a high-pressure swivel joint. It was possible to operate the press but yield was poor due to massive breakthrough of CO_2 cooling the press cylinder down. In order to shift the CO_2 inlet point farther into the throttling position, a second set-up was realized with gas injection into the press head (fig. 4 middle, type III) with the same dissatisfying result. Both methods may work with larger screw-presses with at least two throttling sections to retain the CO_2 in between them (type IV, tab.1), but the lab version does not. Due to the same reason injection type IV could not be investigated with the available press-unit in this work. In all cases temperature decline caused by CO_2 expansion at the press-cage or strainers has to be taken into account.

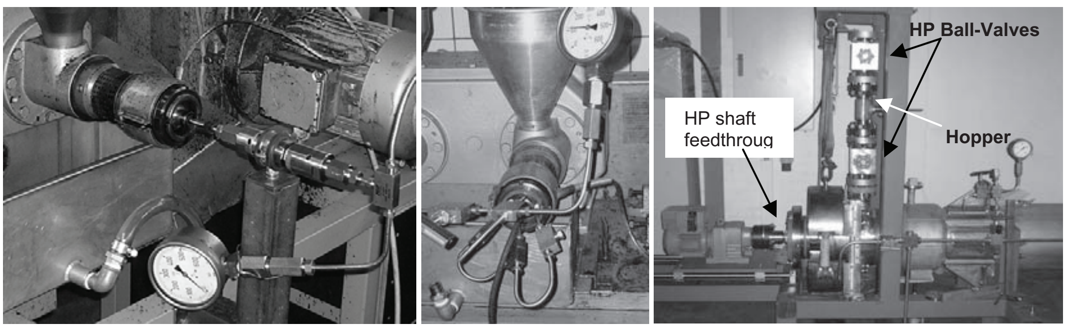


Fig 4. Experimental set-ups. Left: CO2 into screw (type II), middle: CO2 into head (type III), right: HP CO2 chamber system, p max 32 MPa (type IV)

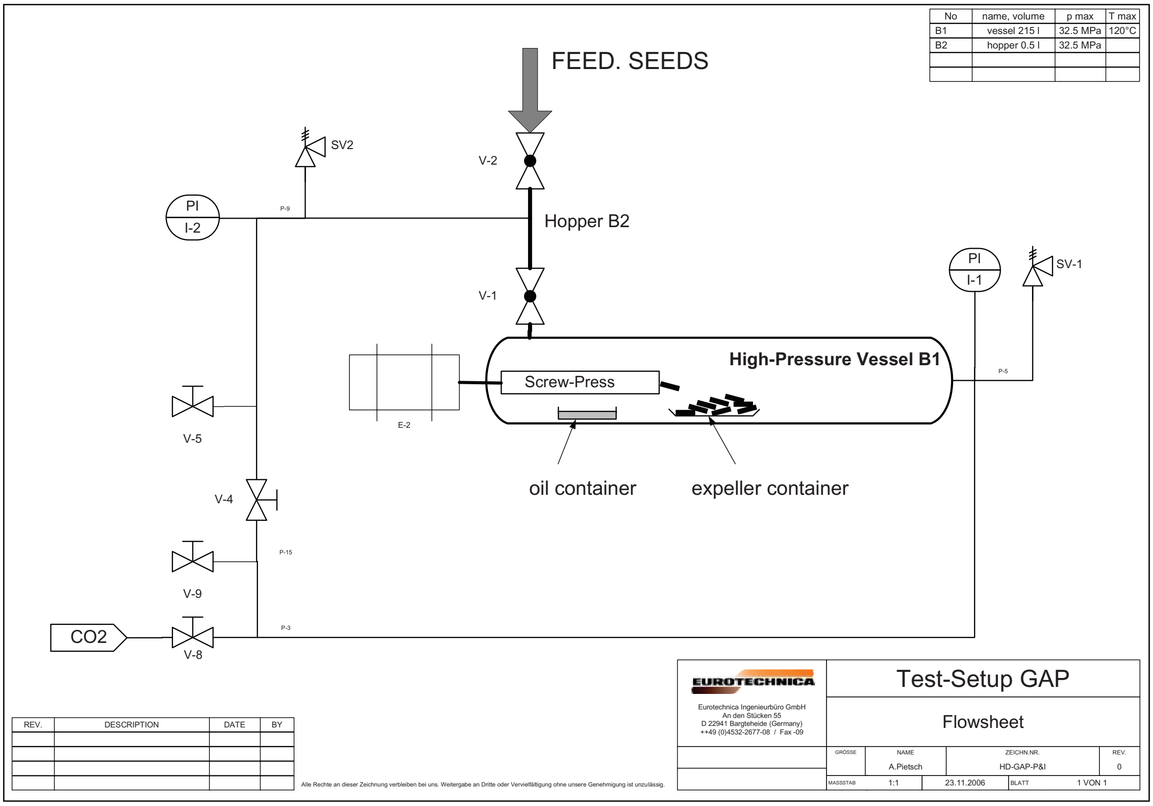


Fig 5. Flowsheet pilotplant: high-pressure chamber system for screw-press

In a second step, the screw press was built into a high –pressure vessel (fig.5). The unique advantage of this set-up (type V compared to type IV) is the possibility to prolong the contact time of the seed material with the CO_2 before the actual squeezing. This can be significant for the outcome of this new technology as previous work has shown[2]. Operation with this setup was possible, the press operated successfully inside the pressurized vessel. Unexpectedly the performance did not improve but rather fell off. The first finding was, that the optimum nozzle size for optimum yield with unmodified press did not work in a pressurized CO_2 at all (tab.2.). To get the press in operation at unaltered screw speed the nozzle size had to be increased. With this increased nozzle size experimental oil yield was lower with the application of CO_2 although the expeller appeared much more deoiled and fluffy (see tab.2 and fig.5). Both effects need further research and may be explained by a reduced friction inside the press. Probably the mechanical press-forces are also reduced by the superimposed system pressure**.** The possible solutions to these new findings can be on one side the alteration of the feed properties in order to increase mechanical friction inside the press (e.g. by lowering the feed material moisture below 7%) and/or evaluation of an injection system with at least two throttling zones (type IV). In the latter case superimposed high pressure gradient to the outside of the press body may be beneficial to enhance oil drainage. Summing up gas assisted screw-pressing is still not fully understood and a highly complex process.

Table 2. Pressing results with encapsulated screw-press at 16 MPa, 65°C, 25 rpm, feed moisture 7,1%w

	without CO2	with CO2	without CO2	with CO2
Nozzle diameter [mm]	**6**	**6**	**8**	**8**
Fat content feed [%w]	45.2%	45.2%	45.2%	45.2%
Fat content residue [%w]	13.9%	*)	17.0%	24.0%
Oil Yield [% of feed]	35.5%	*)	32.6%	24.5%
Oil Yield [% of oil max]	78.5%	*)	72.2%	54.2%
Axial pressure in press head	8.6 MPa	n.d.	n.d.	n.d.

*) malfunction, press was blocked

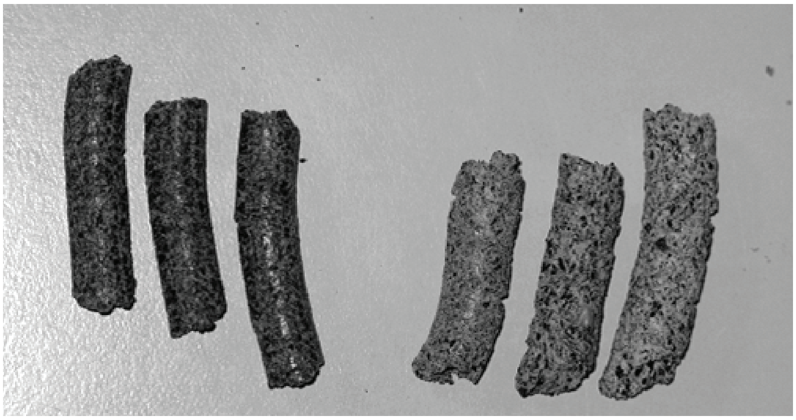
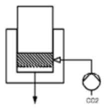
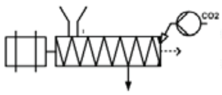
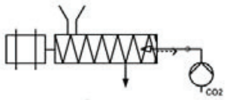
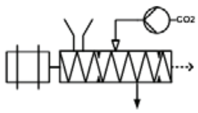
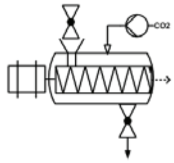


Fig. 6. Rresidue from pressing. Left: without CO_2, right: with 16 MPa CO_2

4. Conclusion

Enhancement of oil yield is very attractive since it has the potential to abandon the not unproblematic seed extraction processes with organic solvents like hexane. Screw-Pressing of oil seeds in presence of high-pressure CO_2 is technical possible, a demonstration plant was realized. In contrast to effectual uniaxial gas assisted pressing, surprisingly the oil yield did not improve with a screw press implemented into a high-pressure environment. Probable reason is reduced mechanical friction inside the press. This drawback could possibly be compensated by moisture adjustment, which is to be investigated in the future. Gas assisted pressing with larger screw presses, at least two throttling zones and high pressure gradient towards the outside of the press body seems to be the most promising design for this new process. Table 3 summarizes this work.

Table 3. Investigated Injection principles of gas assisted mechanical pressing, evaluation

Injection type	**I) Uniaxial press**	**II) CO2 into head, one throttling zone**	**III) CO2 into screw, one throttling zone**	**IV) CO2 into cylinder between at least two throttling zones**	**V) Press inside CO2 vessel**
					
advantage	Long residence time. forces easy to control.	Continuous. Simple design.	Continuous.	Continuous.	Continuous. long residence time in HP gas
dis-advantage	Batch. no agitation.	Short residence time.	Short residence time.	Short residence time. Needs large press.	High investment, complicated lock-hopper systems.
authors experience	Yield improved significantly	Not beneficial, CO2 leaks and cools press down	Not beneficial, CO2 leaks and cools press down.	none so far	Not beneficial, low yield.

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