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PRODUCTION OF VEGETABLE OILS IN DECENTRAL PLANTS AND ASPECTS OF QUALITY MANAGEMENT - INVESTIGATIONS ON PLANTS IN PRACTICE TO OPTIMISE THE PROCESS

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ABSTRACT: Besides central oilmills oilseed processing is possible in small decentral units with capacities of 0.5 to 25 tons of oilseed per day.20 plants were examined in practice on processing values and quality parameters. Processing values like oilseed throughput rate, oil yield, energy consumption and temperature are very different. A great potential to optimize the systems is shown by these facts. The values of quality parameters are not as different as expected. The processing capacity measured is 0.1-19.5 t/d (mean: 5.2 t/d), the oil yield amounts to 66.7-87.3 % (mean:77.6 %). Very great differences shows the energy demand with values from 0.08-0.33 GJ/t oilseed (mean: 0.16 GJ/t).

1 INTRODUCTION

The processing of oilseeds is usually done by great industrial oilmills (**central plants**) with a daily capacity up to 4000 tons oilseed, each. In Germany about 12 central oilmills are situated along the great waterways (Figure 1).

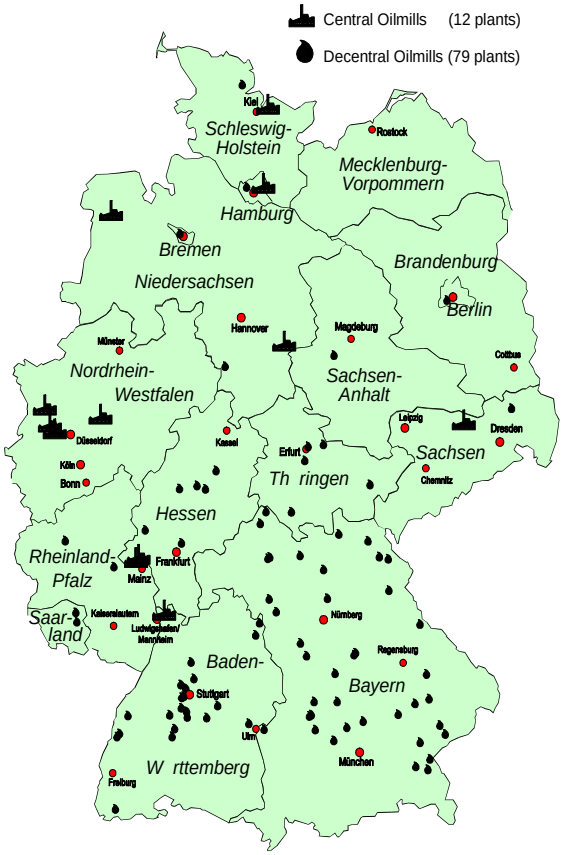

Figure 1: Central and decentral oilmills in Germany (without claim to completeness)

These plants work with pre-pressing, solvent extraction and several refining steps. Their central location partly causes very long ways of transportation of the oilseed and the products.

On the other hand it is possible to gain vegetable oil in small units which are called **decentral plants**, for example organized by agricultural co-operative societies. 79 plants are known in Germany at this time and it is supposed that there are further units. The capacity amounts to 0.5-25 tons of oilseed per day, each. Decentral plants have advantages regarding logistical aspects, transportation costs, material cycles and manufacturing of special products. Predominantly in regions with great distances to the next central oilmill oilseed processing in decentral plants does make sense. As shown in Figure 1 the most decentral oilmills are located in Southern Germany with about 35 in Bavaria. For this technique two aims are very important: **preservation of environment** (short transportation distances, no use of solvents, reduction of energy demand...) and **increase of profit for agriculture** (lower production costs, special products with high prices). Decentral oilmills have to meet the following requirements:

- suitable infrastructure for the oilseed which will be delivered and a suitable market for both products, vegetable oil and press cake,
- the process should be as simple as possible to save investigations and operating costs,
- the quality of the oil produced must be sufficient for each kind of utilization.

Therefore it is necessary to know the influences on technical and quality deciding properties under conditions in practice.
In the following the both techniques will be introduced.

2 OILSEED PROCESSING IN CENTRAL AND DECENTRAL PLANTS

2.1 Processing of oilseeds in central plants

The general process is shown in Figure 2.
Cleaning and **drying** are necessary for proof facility function and high product quality. **Crushing** is done with crushing barrels with smooth or fluting surface. During the stage of **conditioning** the rapeseed is treated with steam for 15-30 min at a temperature of 80-90 °C. This process improves oil separation, deactivates some enzyme systems and adjusts a proper moisture content.

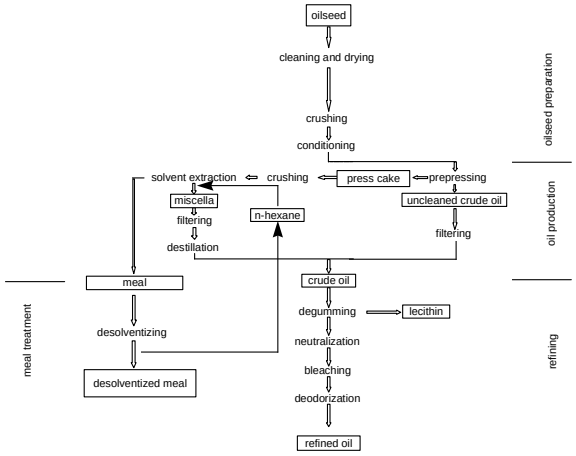

Figure 2: Process for oiseed processing in a central oilmill

Oilseeds with an oil content over 20 % (e.g. rapeseed) are **prepressed** with a continuous working screw press. 50 % of the oil content is extracted with this method. The solid residues from prepressing (press cake) are crushed and transfered to the solvent extraction. During **solvent extraction** nearly the residual vegetable oil is removed from the crushed press cake by a solvent (hexane). The mixture of vegetable oil and hexane (miscella) has to be filtered and afterwards to be distilled in order to remove the solvent from the vegetable oil and to lead it back to the process. The solid residues from solvent extraction are called meal. It contains about 30-35 % first. Therefore the hexane has to be removed from the meal by **desolventizing**.
Because a great amount of unwanted substances is also solved by this process the raw oil must be refined. The step of **degumming** mainly removes phosphatides and the **neutralization** free fatty acids. During the **bleaching** pigments like carotinoides or chlorophyll, traces of metals and sulfur compounds are removed from oil. The **deodorization** with the removal of odour and taste compounds by steam distillation under vacuum completes the refining process. Sometimes waxes are removed by **winterisation**. After refining the vegetable oil has the quality of edible oil. The oil yield by this technique is about 98 %, related to the oilseed´s oil content. The energy consumption of this technique is about 1.7 GJ/t oilseed; 0.7 GJ of it fall to the refining steps.

2.2 Processing of oilseeds in decentral plants

As mentioned in chapter 1 the technique of a decentral plant should be very simple, so the process can be reduced to the following steps (see Figure 3):

- cleaning, drying and possibly crushing of the oilseed,
- pressing by a screw press,

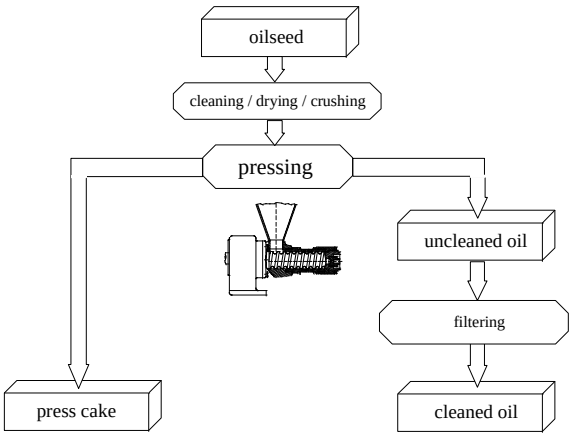

Figure 3: Process for production of rapeseed oil in a decentral oilmill

- purification of the oil by e.g. filtering.

An example for the structure of a decentral oilmill is given in Figure 4. The oilseed is transported by a chain conveyor and an elevator through an instantaneous scale to record the oilseed throughput in an interim container. A further elevator conveys the rapeseed to the preparation facility. **Cleaning** and **drying** are necessary to proof facility function and high quality of the products.

Preheating of the oilseed like the conditioning in a central plant would lead to high amounts of phosphatides in the rapeseed oil. The preheating facilities which sometimes is installed in decentral plants mostly use the exhaust heat of the press cake for warming up the seed by a few Kelvin with advantages especially in winter. Some oilmills have a crushing unit to cut up the oilseed before pressing. This depends on the type of screw press. After preparation the oilseed is **pressed** with a continuous working screw press which is constructed either with a cylindric press cage with steel bars or with a perforated press cylinder.
The press cake leaves the press into a chain conveyor which transfers it to the store. The uncleaned rapeseed oil runs into a crude-oil tank with a stirring facility. A very important criterion of oil quality is the content of solid matter which consists of abrasion from oilseed grains. For

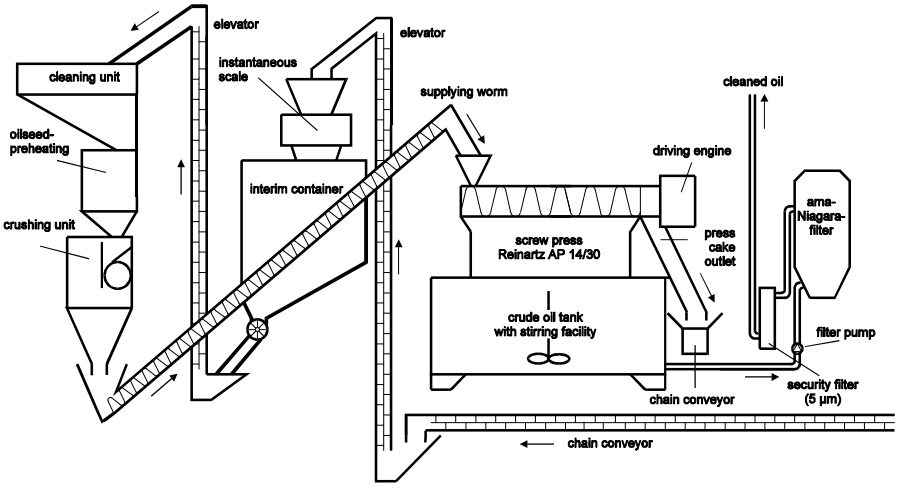

Figure 4: Example for a decentral oilseed processing plant

every kind of use these solids must be removed from the oil to avoid blockage of technical components and accelerated oxidation. Therefore the crude oil is **cleaned** by a vertical pressure filter, a chamber filter press or simply by a settle tank. After this step a security filter with a fineness of 5 µm is necessary in any case.

3 PURPOSE

In the last years several basic research projects were carried out to investigate the process of decentral plants. The purpose of the project shown in this paper is to test the knowledge, acquired by basic research so far, in practice with the aim to optimise the process considering technical reliability, economy, energy consumption and quality management. This work is supported by the Bavarian Ministery for Nutrition, Agriculture and Forestry.

4 APPROACH

A uniform amount of rapeseed (variety „Wotan“ from one field, harvesting season 1996) with an oil content of 44.7 % (fresh matter) and an average water content of 8.13 % were processed in 20 different decentral plants in Bavaria with altogether 23 screw presses. Thereby processing values as well as quality parameters of the products were determined. The purification process was not yet taken into consideration.
The examined presses had capacities from 15 to 1000 kg/h according to informations of manufacturers. 18 of them are screw presses with a press cylinder with steel bars, 5 of them are presses with a perforated cylinder. A pre-heating facility is installed at 11 plants, a crushing unit at 2 presses. The used presses are: Reinartz: 14, Strähle: 2, Keller: 1, Zordan: 1, Monforts: 1, others: 1 presses.

5 RESULTS

5.1 Processing values

Throughput rate:
The average throughput rate of oilseed is 214.5 kg/h with a minimum of 5.1 kg/h and a maximum of 811.1 kg, depending on the press type as shown in Figure 5. The calculated daily capacity (24 h operation) ranges from 0.1 to 19.5 t/d (mean: 5.15 t/d), the yearly capacity (330 days operation) from 40 to 6424 t/a (mean: 1699 t/a). From this results a yearly oilseed area of 13-2072 ha (mean: 548 ha) with a rapeseed yield of 3.1 t/ha. The total capacity of the examined plants is 39400 t/a (12710 ha/a).

Oil yield:
A very important criterion for economy is the oil yield which can be achieved by the pressing process. The oil yield is related to the oilseed´s oil content which is 44.7 % in the present case. According to expectations the oil yield by this simple process is lower than by the solvent extraction in central oilmills with oil yields up to 98 %.

77.6 % of the oil content (average) could be gained as cleaned oil with a minimum of 66.7 % in the poorest plant and a maximum of 87.3 % in the best plant. There are no large differences between screw presses with perforated press cylinder and with press cage; but there are some products which have a poorer oil yield (Figure 6). The result of a lower oil yield is a higher residual fat content of the press cake which improves the feed quality.

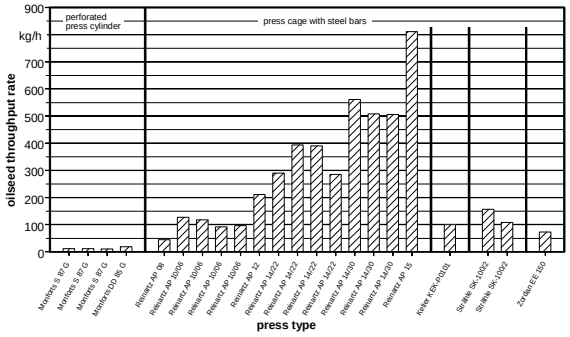

Figure 5: Oilseed throughput rate of different screw presses

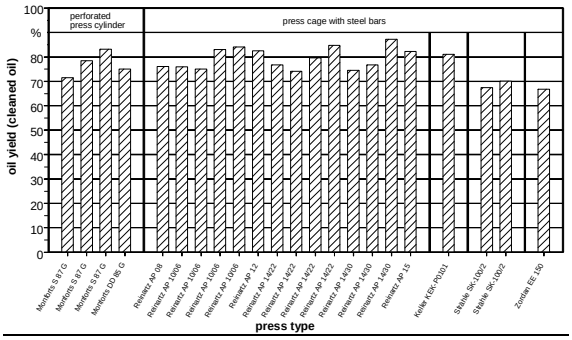

Figure 6: Oil yield of different screw presses

Energy consumption:
The specific energy consumption can either be related to the processed oilseed or to the produced cleaned oil, so that the criterion oil yield is included. Figure 7 shows both values (left and right bar) for the examined screw presses. There is a great influence of the used motor. If the screw presses with perforated cylinder for example would be extended by one or more further press units by using the same motor; the energy demand would decrease. The average energy consumption amounts to 0.16 GJ/t oilseed (0.43 GJ/t oil) without energy for oil filtering (minimum: 0.08 GJ/t (0.22 GJ/t oil), maximum 0.33 GJ/t (0.88 GJ/t oil)). The energy consumption of the whole process in central oilmills amounts to 1.7 GJ/t oilseed, so that energy can be saved by oilseed processing in decentral plants.

Process temperature and temperature of leaving oil:
The term „cold pressed“ is only fixed by the „German manual for foodstuffs“ with a maximum temperature of 40 °C for the oil when leaving the oil press. The average oil temperature of the examined presses is 36.2 °C; the most plants can keep the limiting value which is also important for technical use. Bt there are some single cases with temperatures up to 51.5 °C (Figure 8).

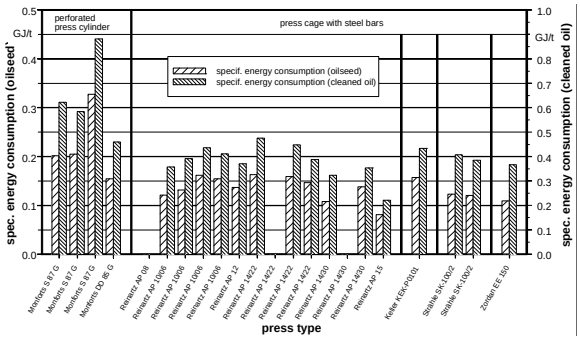

Figure 7: Specific energy consumption of different screw presses

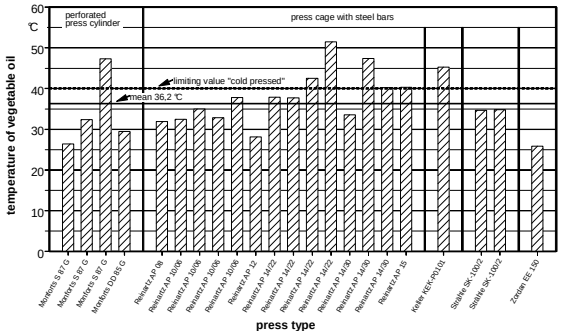

Figure 8: Temperature of leaving oil

The oil temperature depends on the temperature of the processed oilseed and on the temperature of important screw press components, such as press cage or press head temperature. For the presses with press cage the connection is shown in Figure 9.

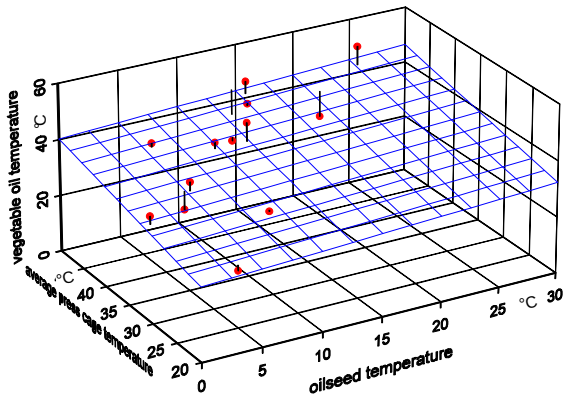

Figure 9: Temperature of leaving oil depending on temperature of oilseed and press cage

5.2 Quality parameters

Vegetable oil quality is not yet fixed for the most uses, but it is necessary to work out quality standards like DIN, EN or ISO norms. The work group „Dezentrale Pflanzenölgewinnung“ worked out a preliminary quality standard for rapeseed oil for the use as a fuel in 1996 which is presented in an own paper in this proceedings.

One of the most important quality parameters is the content of solid matter, analysed according to DIN 51 491-A with a parameter called „**whole impurification**“ („Gesamtverschmutzung“). By the quality standard a limiting value of 25 mg/kg is fixed. For choosing the proper technique with the optimal conditions it is necessary to know the whole impurification of the uncleaned vegetable oil after pressing. Depending on the properties of the oilseed (which were nearly constant for this investigation), the press type and the pressing conditions there are great differences between the examined plants as shown in Figure 10. This must be considered for settle or filtering technique. Because this technique was not subject of the presented investigation, the values for the cleaned oil are not shown.

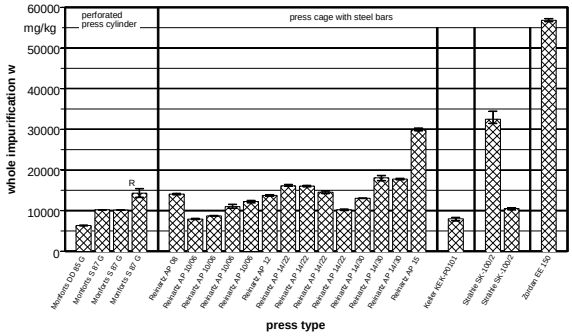

Figure 10: Whole impurification of the rapeseed oil (leaned on DIN 51 419-A

The **water content** influences hydrolyses but also corrosive effects. Therefore by the quality standard the water content is limited at 1000 mg/kg. The results show that in all cases this limiting value was not reached. The average water content is 501,5 mg/kg with a minimum of 381,0 mg/kg and a maximum of 712,0 mg/kg.

The degumming step of the process in central oilmills reduces the content of phosphatides which is analysed as **phosphorus content** to values of 0-5 mg/kg P. One important requirement of the oilseed processing in decentral plants without any refining is to get vegetable oil with a very low phosphorus content (limiting value according to preliminary quality standard for fuel: 25 mg/kg). Phosphatides lead to problems within every kind of technical process by hydratisation and therefore blocking filters and nozzles for example. Further they reduce oxidation stability and are poisons for exhaust gas cleaning systems like oxidation catalysts. Therefore it is very important to lead phosphatides which are compounds of the oilseed grain into the press cake and so to achieve a phosphorus content as low as possible. The values of the rapeseed oils from examined plants are between 1 and 4 mg/kg and are clearly lower as the limiting value.

The content of **metals** like iron, copper mostly are less than the lower proofing limit.

6 CONCLUSIONS

The 20 decentral oilseed processing plants examined show a great variety regarding processing capacity. The oil yield can be optimized by using proof screw presses and conditions. There are great differences regarding energy demand and thus a potential to optimize the process. The oil quality between the plants is not as different as expected.