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Thermal oil extraction from rapeseed

High frequency energy improves mechanical pressing yield

A thermal pre-conditioning of rapeseed basically enables an increase in the efficiency of mechanical oil extraction. According to the findings so far, negative effects on oil quality are not to be expected; in fact partly through the inactivation of lipolytic enzymes an improvement in quality can be achieved. The application of high frequency energy in the thermal pre-conditioning of oilseeds represents, therefore, a fundamentally conceivable starting point for future developments in oilseed processing.

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Especially in the food industry sector, the application of high frequency (HF) and microwave energy in the preparation and disinfection of convenience food is nowadays an everyday procedure. Less known is the fact that these energy forms can in principle also be used for other purposes within the context of processing agricultural products. An example here is the thermal treatment of rapeseed to improve oil extraction efficiency and quality. This process has, up until now, had no practical relevance, but some advantages appear to offer potential for future applications.

Physical fundamentals of high frequency heating

For a better understanding on the use of HF energy in thermal applications, one should first consider a few of the physical fundamentals [1, 2].

The energy form utilised in the reported trials is high frequency electromagnetic waves with an oscillation frequency f of 27.12 MHz which represents the equation (1)

$$\lambda_0 = \frac{c}{f} \quad \left(\text{mit } c_{\text{Luft}} = 3 \cdot 10^8 \, \frac{\text{m}}{\text{s}}\right) \tag{1}$$

which represents an unrestricted wave length of λ_0 from around 11 m.

The mechanics of heating in this case differs from conventional methods where necessary energy for increasing the temperature in the form of heat through convention, conduction or radiation is directed from outside. In this case, the energy transfer basically takes place over the high frequency field without heating the surroundings. The heat development takes place first of all through interaction with polar substances and an interconnected absorption within the product interior of the energy stored in the electromagnetic field („Principle of interior heating“). Here, diplocharacter material („Dielectrica“) contained within the sample material develops the tendency to arrange itself according to the electromagnetic alternating field. This leads to a rotational movement caused by the inertia of the molecules which in turn cause a rise in temperature through increased intermolecular friction. The extent of this interaction is determined by the permeability of the material for HF waves and mathematically is written as a complex factor mostly based on the loss-free dielectric permeability of the vacuum:

$$\frac{\varepsilon^*}{\varepsilon_0} = \frac{\varepsilon'}{\varepsilon_0} - j \cdot \frac{\varepsilon''}{\varepsilon_0} = k' - j \cdot k'' \tag{2}$$

ε^*: dielectric permeability for HF waves
ε_0: dielectric permeability of HF waves in vacuum
k': relative dielectricity constant (storage share)
k": relative loss figure (loss share)

Through the absorption of radiation in the dielectric product there develops a dissipation rate PV

$$P_V = 2 \cdot \pi \cdot f \cdot \varepsilon_0 \cdot k'' \cdot E_{\text{eff}}^2 \tag{3}$$

f: oscillation frequency of the electromagnetic waves
ε_0: absolute dielectricity constant in vacuum
E_{eff}: effective field strength

which finally leads to a temperature increase (ΔT) for a differentially small volume unit in connection with the application length (Δt):

$$\Delta T = \frac{P_V \cdot \Delta t}{\rho \cdot c_P} \tag{4}$$

ρ: mass of the dielectric product
c_P: specific heat capacity of the dielectric product

Because of the HF energy absorption through the dielectric product, with increasing depth of penetration an exponential reduction of the field strength and the dissipation rate is recognisable and this, with large bodies, leads to development of a heat production zone in the outer areas. The theoretical penetration depth of the HF waves is of particular importance in connection with this. As a rule, they are defined as the penetration depth with which the loss performance density is reduced to 37% (≈ 1/e) of its initial value. Theoretically this applies to an infinitely large homogeneous body, the so-called „physical half space“, which the formula (5) approaches

$$s_{\text{theoret.}} = \frac{\lambda_0 \cdot \sqrt{k'}}{2\pi \cdot k''} \tag{5}$$

λ_0: wavelength in vacuum

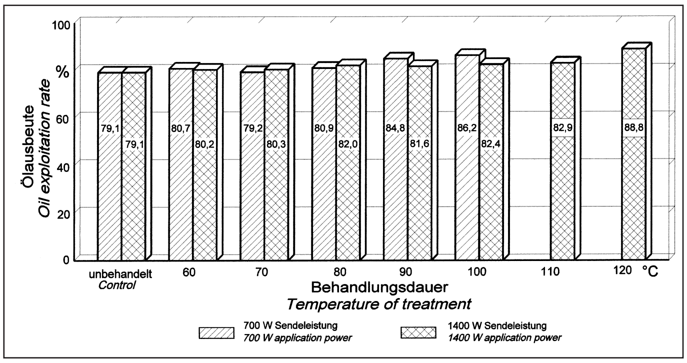

Fig. 1: Influence of thermal pretreatment of rapeseed using Rf-energy (f=27.12 MHz) with different power stages and temperatures on oil yield, when mechanically extracted

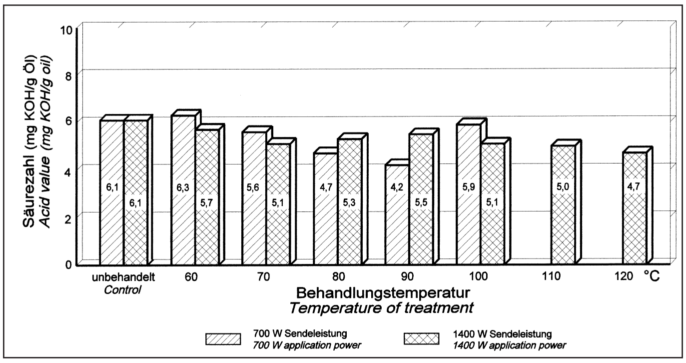

Fig. 2: Influence of thermal pretreatment of rapeseed using Rf-energy (f=27.12 MHz) with different power stages and temperatures on the acid value, when mechanically extracted

in description. As a rough rule of thumb for practical applications it can be taken that the performance of the FH field over a section which represents one tenth of the wavelength is reduced by about 37% .

Finally, it must be pointed out that in the case of biological material we are not dealing with homogeneous bodies of uniform material. Instead we are dealing with a mix of different substances which indicate irregular concentration-distribution of dielectrically different active materials. This is why the presented fundamentals make precise indications of heating performance possible only to a very limited extent. The result is that an irregular temperature distribution often appears with a more strongly heated outer layer where the main part of the field energy is absorbed. Because of the large wavelengths of around 11 m, one can, however, assume with the application of HF energy that this effect hardly ever makes itself felt in that the measurements of the relevant agricultural products in comparison with the wavelengths are very small. The marginal zone covers in such a case such a large area that, because of the relatively small mass of material, the entire sample is involved. In principle, a stronger heating of this area takes place, but as far as practical applications are concerned one can assume an even heating and a homogeneous temperature distribution over the whole sample material. This is a particular advantage of the application of HF energy which cannot be realised when using microwave energy for thermal applications. This is because in such a case, as opposed to the application of HF energy, very pronounced thermal marginal zones – so-called „hot spots“ – appear from wave reflections as well as superimpositions in the comparatively undisciplined microwave field.

Structure of trial plant

Generally, the equipment for the presented research work comprises an HF generator, with capability of producing the necessary basic oscillation of 27.12 MHz, an automatic adaption and control network allowing an optimal transformation of the HF energy in the material, and the applicator. This is built like a simple plate condenser and comprises two aluminium plates as electrodes. These plates can be position from one another at variable distances. Between these plates is placed the sample. Finally, the distance between the plates is reduced to such an extent that both condenser plates stand in direct contact with the sample. This is important in that an air hole between plate and product influences the electromagnetic field and through that, the heating performance. In order to succeed in heating the sample despite the electrical insulation action of the air, very high voltage differences of up to several kilovolts have to be created. These must be just short of the critical electrical current bridging strength so that spark transmission and burning can occur.

Trial method

Featured in the trial were 500 g samples of conventional 00-rape placed in rectangular boxes of dielectrical-inactive plastic positioned between the condenser plates and heated to an end temperature of from 60° to 120 °C with two different power levels (700 W and 1400 W). Parallel to this, an untreated control sample was tested for comparisons with both trial series. The treated material was crushed through a laboratory auger press of type IBG Montfords CA 59 G under constant conditions (auger head temperature 70 °C, auger rpm 50 min^{-1}, chamber Ø 6 mm) and the oil collected by gravitation. Based on these values the oil yield was calculated as a relative factor in that the collected raw oil was compared with the total oil content of the original material (oil content 47.8 % according to Soxhlet). For the subsequent quality analysis, the raw oil was cleaned by sedimentation process and finally analysed for free fatty acid content (acid number) according to the official test method in §35 LMBG [3].

Results

Concerning oil yield (*Fig. 1*), it can be seen that there is a notable increase in the degree of pressed oil with 79.1% won from the control sample up to a maximum 88.8 % in the best variation which featured a transmission power of 1400 W and a temperature of 120 °C. The tests indicated that the trial series with the higher transmission power of 1400 W, especially in the higher temperature re-gions above 90°C, showed a more pronounced increase in oil yield compared with the variants with lower transmission performance. However, the series with the lesser energy input could not be carried out to the end because of technical reasons. Here, the transmission power was not enough to achieve the higher temperatures because of too high heat losses from the sample containers.

With the free fatty acids in the oil there was a readily recognisable tendencial reduction of 6.1 mg KOH/g oil for the control variants to a minimal 4.2 mg KOH/g oil for the control variants (*Fig. 2*). Notable is that, but for one exception, all the samples indicated lower, and therefore better, values compared with the untreated control variants. Further investigations on the same samples showed that this effect is traceable back to an efficient inactivation of lipolytic enzymes through the HF treatment. Through this an increased separation of fatty acids from the triglycerides is prevented during the pressing – although the material and the resultant separated oil reached temperatures that offered optimal reaction conditions for these enzymes.