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Isolation of Tomato Seed Oil From Tomato Waste by Application of Supercritical Fluid CO_2 Extraction

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Abstract: The goal of this work is isolation of tomato seed oil from the tomato waste (skin and seed) from tomato processing industry by utilization of non-conventional, green solvent technology. In the frames of experimental research, the influence of working parameters (temperature, pressure and extraction time) on the total yield of isolated tomato seed oil. Dynamic method for determination of solubility parameter in a supercritical CO_2 has been used to determine the solubility of tomato seed oil in the supercritical CO_2.

Obtained results regarding the influence of operating parameters on total yield of extracted tomato seed oil are presented graphically. The influence of the supercritical fluid' density on the tomato seed oil' solubility was determined based on those results. The chemical composition of isolated tomato seed oil was determined by application of Gas Chromatography.

Keywords: tomato seed oil, solubility, supercritical CO_2

Introduction

Industrial processing of fruits and vegetables results in large accumulation of byproducts that represent potential raw material rich in bioactive components. These tomato processing industry byproducts are sold at low prices or practically given to farmers to be used as cattle food. On the other hand, these byproducts - seeds and skins can be used as a source of vegetable oils and antioxidants (lycopene) by application of appropriate precise process separation methods (Supercritical CO_2 - green solvent) [1].

Non-conventional separation procedure - supercritical fluid CO_2 extraction (SFE-CO_2) conforms to the strict demands of the precise process eco-technologies [2]. It represents a perspective method especially in obtaining eco-friendly extracts from vegetable and animal raw materials. Implementation of SFE for isolation of vegetable oil from tomato seeds results in obtaining high quality and high purity total extract and excludes the presence of organic solvents, heavy metals and some microorganisms [3, 4].

Materials and Methods

Red tomato waste seeds from tomato processing industry were used as a working raw material in the experimental researching. Tomato seeds represent a byproduct of the technological process of processing red tomatoes into tomato concentrate. Tomato waste material had been dried at ambient temperature in absence or direct sunlight. A hydro separation method (G:V = 1:3) was conducted in order to separate tomato seeds from the rest of the waste material, where G - tomato solid waste (skin and seed), V - distilled water. Through the hydro separation process it was established that seeds constitute 37,9 % (wt) of the waste material [5]. After the hydro separation procedure, obtained seeds were submitted to ambient temperature drying process in absence of sunlight. In order to determine the total content of tomato seed oil in tomato seeds, a classical *Soxhlet* extraction process with 70% (vol) ethanol as an extraction solvent, was applied. According to this procedure, the total amount of seed oil is 20.1 % (wt).

Supercritical fluid extraction from working raw material was done in semi industrial pilot plant. The apparatus has extraction and separation vessels of 4 dm^3 and 4 dm^3 in volume, respectively. Maximum working pressure is limited at 500 bar and the extraction temperature can be varied from ambient to 130°C [6]. The sample is loaded into extraction vessel and extracted with supercritical carbon dioxide. Pressure and temperature changes in the separation vessel cause the condensation or precipitation of the soluble components from CO_2 fluid. After separation, CO_2 is recycled.

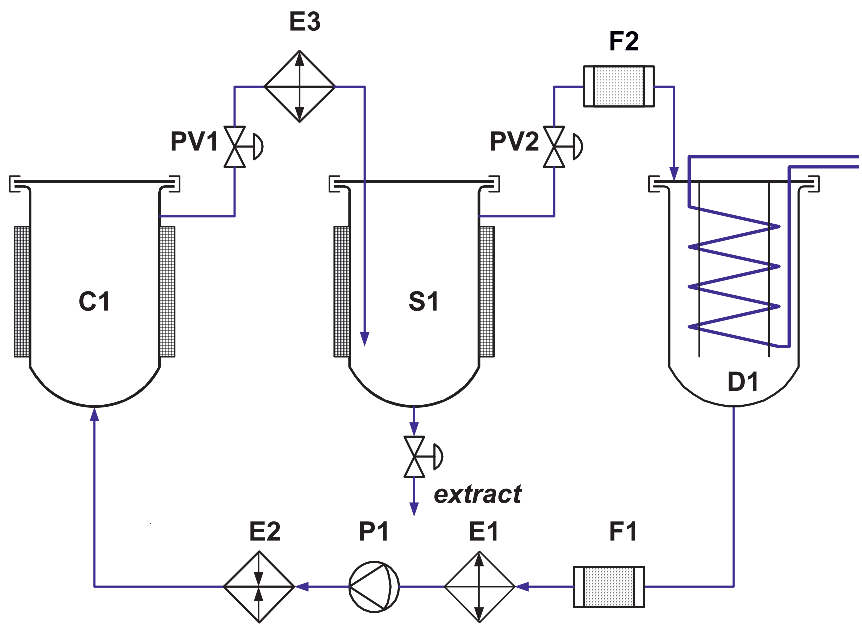

Fig. 1 Schematic flow sheet of supercritical extraction pilot plant (Uhde. Germany)
(C_1 – extractor; S_1 – separator; D_1 – CO_2 tank, $E_{1,2,3}$ - heat exchanger, P_1 - high pressure pump, $PV_{1,2}$ - control valve, $F_{1,2}$ - flow rate control)

Qualitative and quantitative analysis of the obtained extract was performed by GC method. The GC apparatus type was “GL Science GC-353, FID” and silica column type “Chrompack WCOT FFAP-CB, 25 m x 0,32 mm i.d.”

Results and Discussion

The influences of working conditions (pressure, temperature and extraction time) on the total yield of extract and its solubility in the supercritical fluid have been examined during the extraction process on tomato seeds. The separation in all of the experiments was conducted at the following operating conditions: operating temperature of 25°C and operating pressure of 50-55 bar.

Obtained results regarding the influence of the operating pressure on the total yield of tomato seed oil are presented graphically:

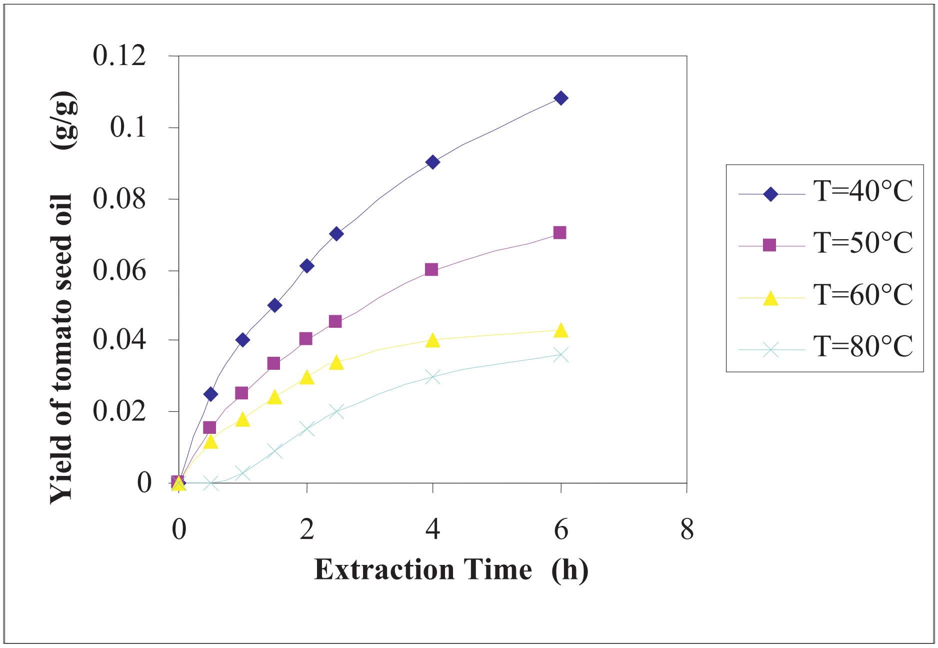

Fig. 2 Influence of operating pressure (P=140 bar) on total yield of seed oil (Operating conditions: Q= 20 kg CO_2 /h; τ = 6h; W= 7.5%; d= 0.27 mm)

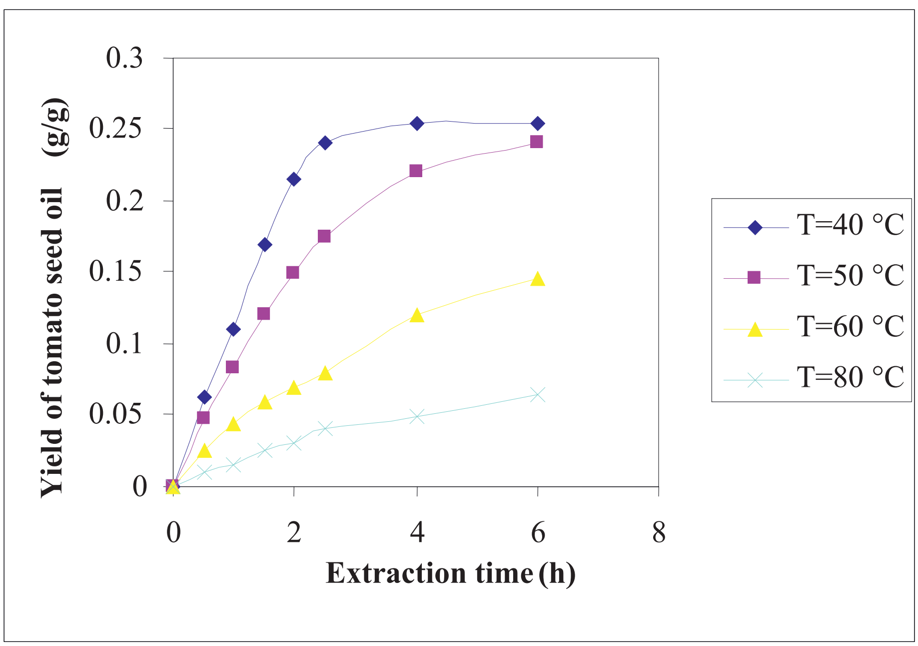

Fig. 3 Influence of operating pressure (P= 210 bar) on total yield of seed oil (Operating conditions: Q= 20 kg CO_2 /h; τ = 6h; W= 7.5%; d= 0.27 mm)

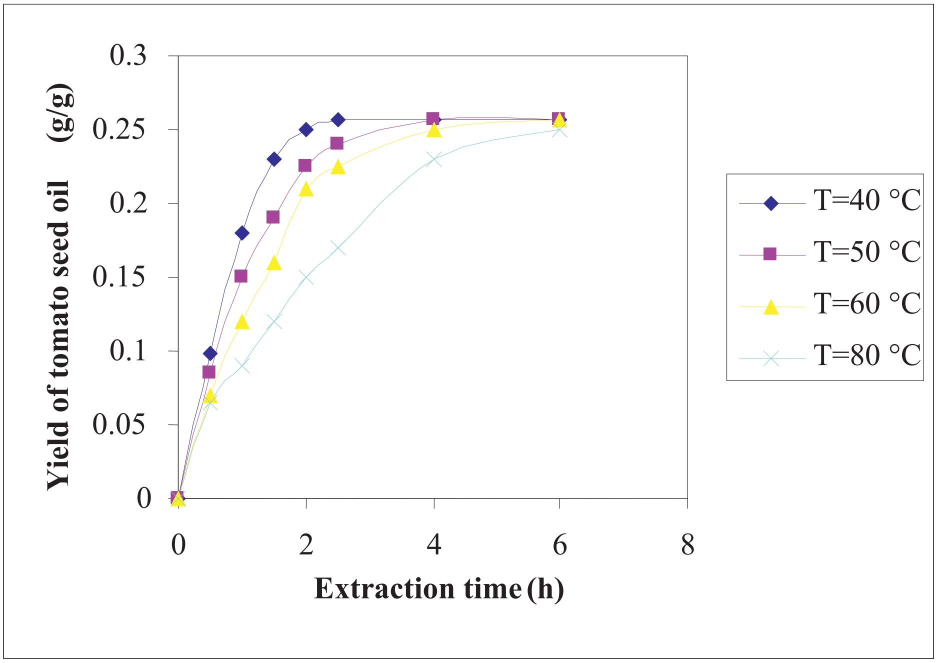

Fig. 4 Influence of operating pressure (P= 280 bar) on total yield of seed oil
(Operating conditions: Q= 20 kg CO_2 /h; τ = 6h; W= 7.5%; d= 0.27 mm)

The analysis of above presented results shows that higher operating pressure at operating temperature of 40°C results in increase of the total yield of extract - tomato seed oil. This phenomenon is also characteristic for higher operating temperatures. On the other hand, higher operating temperatures produce lower yield of total extract, which derives from the lower density of supercritical CO_2. Therefore, it can be concluded that the supercritical CO_2 extraction of vegetable oil form tomato seeds is best conducted at lower temperatures and higher operating pressure, in the CO_2 - PT diagram area of highest density of supercritical CO_2. This means that optimal SFE- CO_2 extraction of vegetable oil from tomato seeds can be achieved at operating temperature of 40°C and operating pressure of 210 bar.

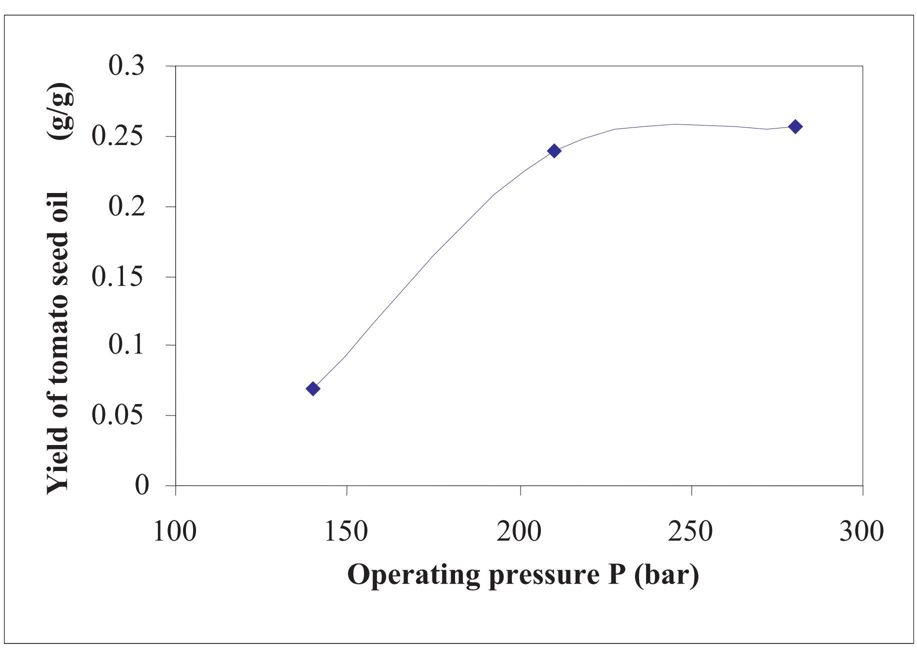

Fig 5. Influence of operating pressure on the yield of tomato seed oil through SFE-CO_2
(Operating conditions: t = 40 ^{0}C; τ = 2.5 h; Q = 20 kg CO_2 /h; d = 0.27 mm; W=7.5 %)

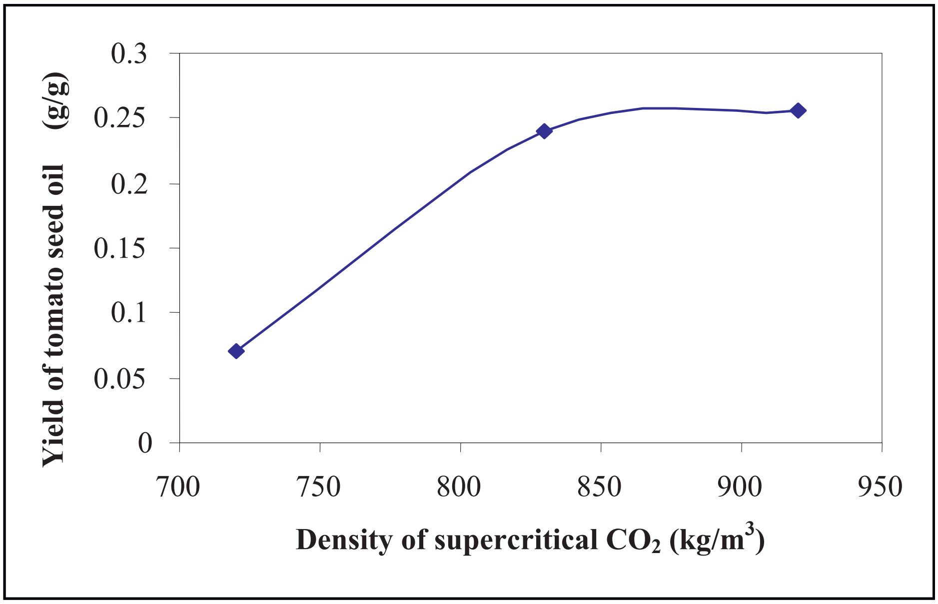

Fig. 6. Tomato seed oil yield variation depending on the density of the supercritical CO_2 at isothermal SFE-CO_2
(Operating conditions: t = 40 ^{0}C; τ = 2.5 h; Q= 20 kg CO_2 /h; d= 0.27 mm; W=7.5 %)

Figures 5 and 6 clearly indicate that an increase of the operating pressure hence increased density of the supercritical fluid, results in higher yield of total extract, when operating at isothermal conditions.

Further experiments (Fig. 7 and 8), conducted in order to determine the influence of the operating temperature, were performed at operating pressure of P= 280 bar. In addition, it has been confirmed once more that an increase of the operating temperature from 40^{0}C to 80^{0}C at isobaric operating regime results in reduction of the total yield of extract. This derives from the poorer solubility of the vegetable oil in the supercritical fluid with lower density.

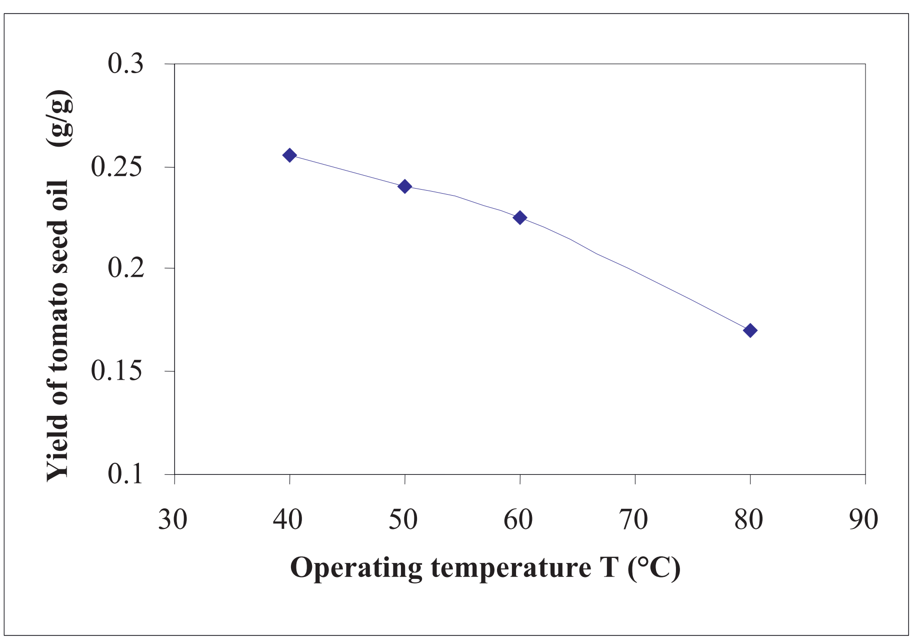

Fig. 7 Influence of operating temperature on tomato seed oil yield at SFE-CO_2
(Operating conditions: P= 280 bar; τ = 2.5 h; Q= 20 kg CO_2 /h; d= 0.27 mm; W= 7.5 %)

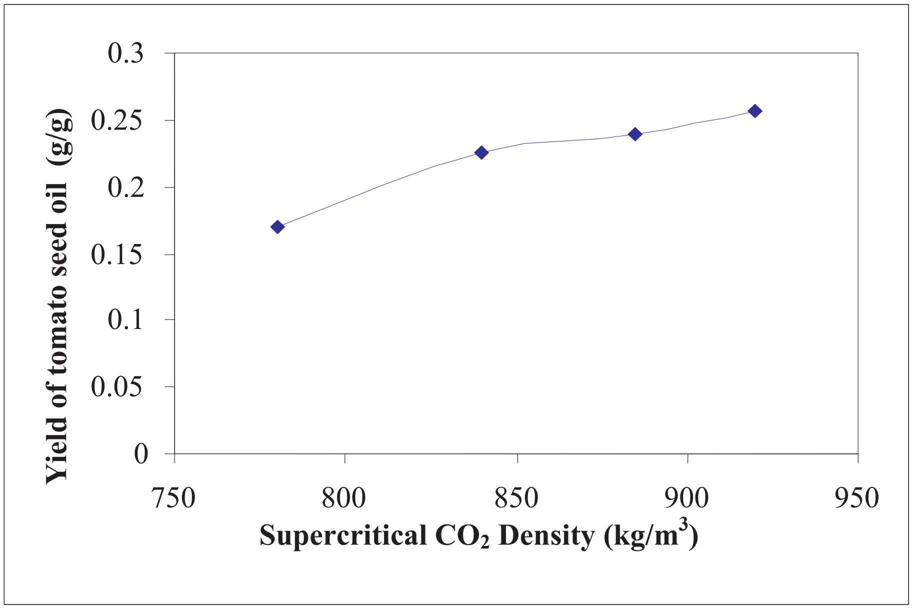

Fig. 8 Tomato seed oil yield variation as a function from supercritical CO_2 density at isobaric SFE-CO_2
(Operating conditions: P=280 bar; τ =2.5 h; Q=20 kg CO_2 /h; d= 0.27 mm; W= 7.5 %)

Series of experiments were performed in order to determine the influence of the extraction time parameter on the yield of vegetable oil, at operating conditions of: P=280 bar and t = 40^0C in a time interval of τ = 0-6 h.

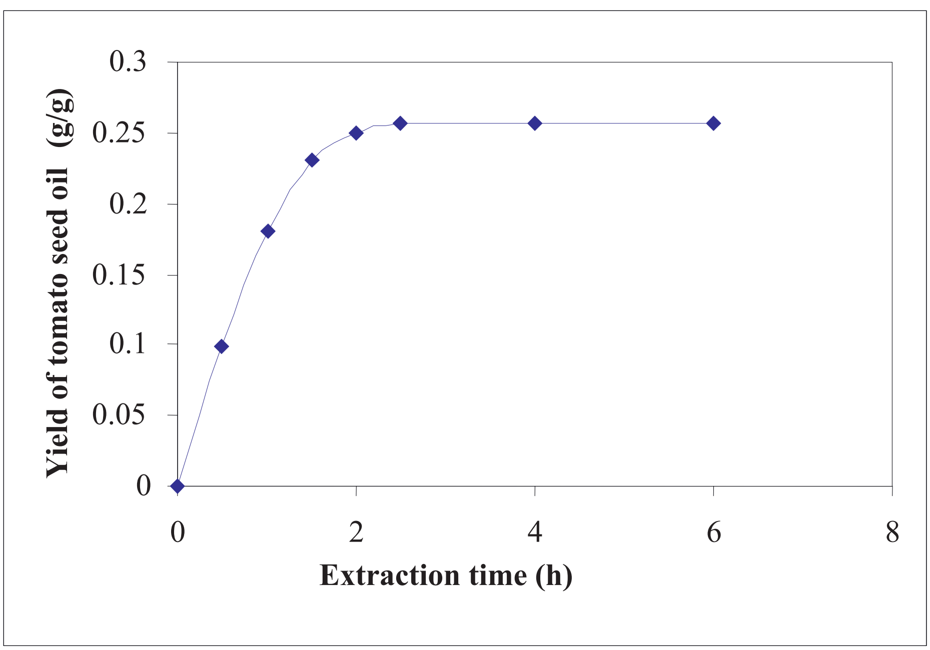

Fig. 9 Tomato seed oil yield variation at SFE-CO_2 as a function of extraction time
(Operating conditions: P= 280 bar; t = 40 ^{0}C; Q= 20 kg CO_2 /h; d= 0.27mm; W= 7.5 %)

Figure 9 suggests that following the initial 2.5 hours, the extraction process enters its equilibrium where a maximal yield of extracted vegetable oil is achieved.

The following figure (Fig.10) presents the functional dependency of tomato seed oil solubility on the operating pressure at various operating temperatures through the SFE-CO_2 process. Obtained results suggest that the highest solubility of tomato seed oil is achieved at operating pressure value of 210 - 280 bar interval and at operating temperature of 40⁰C.

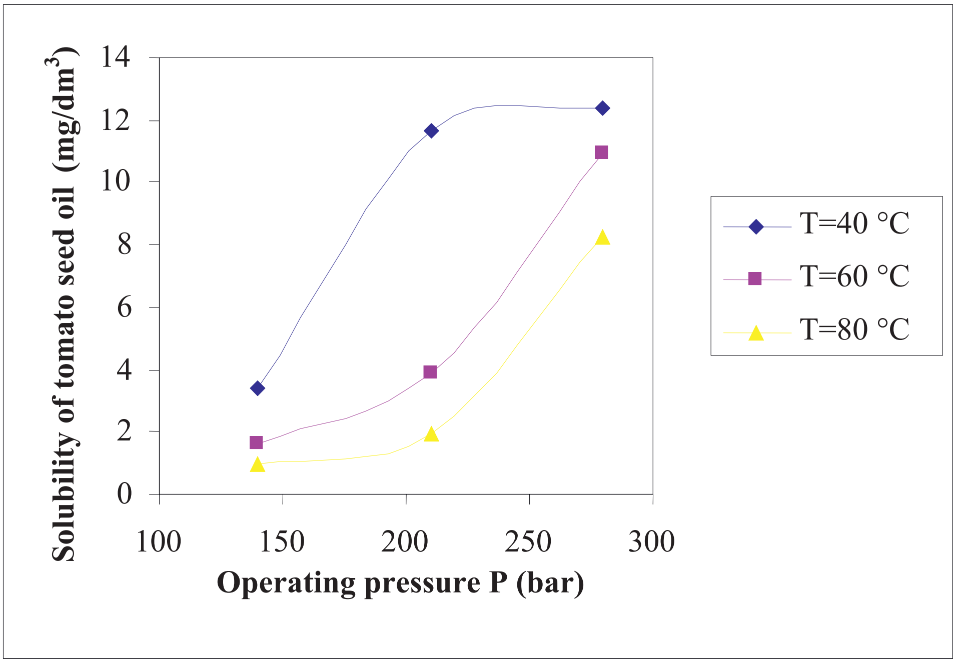

Fig. 10 Tomato seed oil solubility as a function of operating pressure
(Operating conditions: Q= 20 kg CO_2 /h; W= 7.5 %; τ = 2.5 h; d= 0.27mm)

Process parameters' legend:
Q - supercritical CO_2 flow rate [kg/h]
W - raw material humidity [% wt]
d - particle granulation [mm]
τ - extraction time [h]

Quantitative analysis of isolated tomato seed oil by application of Gas Chromatography (GC)

Obtained results regarding the quantitative presence of unsaturated fatty acids through application of gas chromatography on the isolated tomato seed oil are presented in the following table:

Table 1. Unsaturated fatty acid composition (% W/W) in tomato seed oil isolated at P= 280 bar; t = 40⁰C

Time (min)	Yield (%)	C (16:1)	C (18:0)	C (18:1)	C (18:2)	C (18:3)
5	10.2	1.89	5.54	20.96	53.2	5.6
20	27.5	1.99	5.5	20.58	54.0	6.0
30	38.1	2.1	7.2	23.1	53.8	5.8
60	69.5	1.6	7.4	23.2	53.85	6.32
100	94.5	2.86	9.85	24.7	47.1	5.9
140	99.2	4.2	12.5	26.5	40.3	5.01

According to the obtained results regarding the composition of the tomato seed oil, it is evident that the unsaturated fatty acid - linoleic acid (C18:2, $C_{18}H_{32}O_2$, omega-6) constitutes the highest share of the tomato seed oil composition.

Conclusion

Based on the presented results, following conclusions can be drawn:

- Conforming to the zero emission process concept, tomato waste can be utilized for isolation of high quality tomato seed oil, rich in bioactive components, which are of significant importance to the cosmetic, pharmaceutical and food industry;
- Tomato seed oil, isolated and purified through SFE-CO_2, represents potential raw material for a design of new bioactive products. Considering its physical and chemical properties, tomato seed oil is a potential source of unsaturated essential fatty acids. The quantitative ratio of the unsaturated fatty acids is more suitable to the demands of the cosmetic formulations then the same soya ratio;

Overall, considering all of the obtained results, an appropriate procedure for utilization of tomato waste from the canning industry, can be established in order to obtain useful final products.

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