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Effect of hydraulic press parameters on crude palm oil yield

O.K. Owolarafe[1], A.S. Osunleke[2]*, and B.E. Oyebamiji[1]

[1]Department of Agricultural Engineering
[2]Department of Chemical Engineering
Obafemi Awolowo Univeristy, Ile-Ife, Nigeria

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A b s t r a c t. An investigation was carried out on the effect of hydraulic press parameters such as press cage diameter (D) (80, 120, and 150 mm) and wall pore diameter (H) (4, 6, and 10 mm) and expression pressure (P) on crude palm oil yield. The oil yield was found to increase with increase in cage diameter from 80 to 120 mm, after which it decreased as the cage diameter was increased to 150 mm. The volumetric oil flow followed the same pattern. The oil yield and volumetric flow increased with increase in pore size from 4 to 6 mm and decreased as the pore size increases to 10 mm. Increase in pressure form 0.5 to 1.5 MPa was observed to increase oil yield. Statistical analysis of the effect of the processing factors on oil yield indicates that the effect of all the factors were significant at 99%. It was observed that oil yield can be represented by the regression equation: Y=27.76-0.07D+0.33H+5.82P. The results of this study are useful in optimising the design of presses for palm oil extraction.

K e y w o r d s: palm oil, processing, oil yield, parameters, design, optimisation

INTRODUCTION

Processing of palm fruit to obtain palm oil involves five basic operations which are fruit loosening, fruit sterilization, digestion, oil extraction and clarification. Oil extraction still remains a critical bottleneck, particularly at small and medium scale processors in Nigeria (Babatunde *et al*., 1988; Owolarafe *et al*., 2002). In common with many developing countries, small scale processors dominate palm oil business in Nigeria (Badmus, 1991). Oil is usually extracted from oil-bearing material by mechanical expression or with the solvent method (Khan and Hanna, 1983; Fasina and Ajibola, 1990; Owolarafe *et al*, 2003). In palm oil extraction, a third method called aqueous extraction is also employed, particularly at small scale or cottage levels (Owolarafe *et al*, 2006). Mechanical expression by hydraulic or screw press is common in modern palm oil production. However, hydraulic press is common in small scale processors because it is less capital-intensive in terms of initial and maintenance costs (Adeeko and Ajibola, 1990; Owolarafe *et al*, 2002). Hydraulic presses are now available in different versions, but their efficiency seldom exceeds 70%. Several attempts are being made to improve the efficiency of the hydraulic press in Nigeria (Babatunde *et al*, 1988; Badmus, 1991). Recent observations in Nigeria reveal that hydraulic presses are available in a variety of sizes (in terms of cage diameter and pore sizes) without a standard (Owolarafe and Jeje, 2006). This study investigates the effect of hydraulic press cage diameter and cage wall pore size on yield of oil as an insight to optimising the design of the press such that its extraction efficiency can be improved.

MATERIALS AND METHOD

Fabrication of press cages

A galvanized sheet of 3 mm thickness was cut into dimensions (120 mm ΠD) where the height of the cage was 120 mm and ΠD was the circumference of the press cage and D was the diameter of the cage. Holes of 4, 6, and 10 mm diameter were drilled in the sheet metal at equal spacing. The drilled sheets were rolled into a cylindrical cage with the required diameter. The channel for the oil drained from the cage was fabricated from a mild steel of about 5 mm in thickness to provide required strength for it to withstand pressure of the press. The pistons were made of thick metal material and capable of transmitting the force required to press oil from digested mash without failing.

*Corresponding author's e-mail: aosunlek@oauife.edu.ng

Pretreatment of palm fruit

Freshly harvested palm fruits bunches were cut into quarters by axe and the fruits were manually removed, after which 5 kg weight of fruits was taken and washed with clean water. The palm fruits were taken into a small-scale version of the vertical cylindrical sterilizer reported by Hartley (1988), and sterilized with steam at temperature of about 100°C for 90 min. The sterilized fruits were quickly removed from the sterilizer and transferred into a vertical digester reported by Babatunde (1987), where it was digested for 10 min. The digested mash was removed and taken to the press.

Pressing operation

The complete laboratory press (Fig. 1) used for the study consists of well constructed lever arm which works on principle of moment as reported elsewhere (Fasina and Ajibola, 1989; Ajibola *et al*, 2002). Points A and C on the diagram indicate the fulcrum and support for the beam, respectively. A 10 tonne hydraulic jack on the press was used to gradually release the force on the mash through the piston, based on the weight in the container on the lever arm of the press. The mash was weighed before pressing and weighed after pressing to determine the weight of oil expressed.

Experimental design

Based on the earlier work of Babatunde *et al*. (1988) and Owolarafe *et al*. (2002) and Owolarafe *et al*. (2007), a constant sterilization time of 90 min was used in the study. The other parameters, variable, were the pressure and the press design features (cage diameter and pore size). The experimental design is shown in Table 1.

T a b l e 1. Experimental design used in the study

Factors	Level		
Pressure (MPa)	0.5	1.0	1.5
Press cage diameter (mm)	80	120	150
Pore size (mm)	4	6	10

Data collection

The data collected included the oil yield and volumetric flow rate which were calculated in percentages of weight as follows: cage – A , cage and mash before pressing – B, cage and mash after pressing – C, mash before pressing – $B – A$, oil yield $B – C$:

$$\text{Oil yield } (\%) = \frac{B-C}{B-A}\,100 .$$

The volumetric flow of oil was monitored over time and hence the volumetric flow rate data were obtained by the ratio of the oil yield (in volume) to the time(s) of flow of oil. Using the data obtained on the volumetric flow rate, the superficial flow of oil was determined by dividing the volumetric flow rate by the area of wall pores. Volumetric and superficial data have been observed to be very important in modelling of oil expression (Schwartzberg, 1997).

RESULTS AND DISCUSSION

The results of average oil yield at different press parameters and expression pressure considered are shown in Table 2. Tables 3 and 4 show the volumetric flow rate and superficial flow rate of oil, respectively, at each level of processing combination.

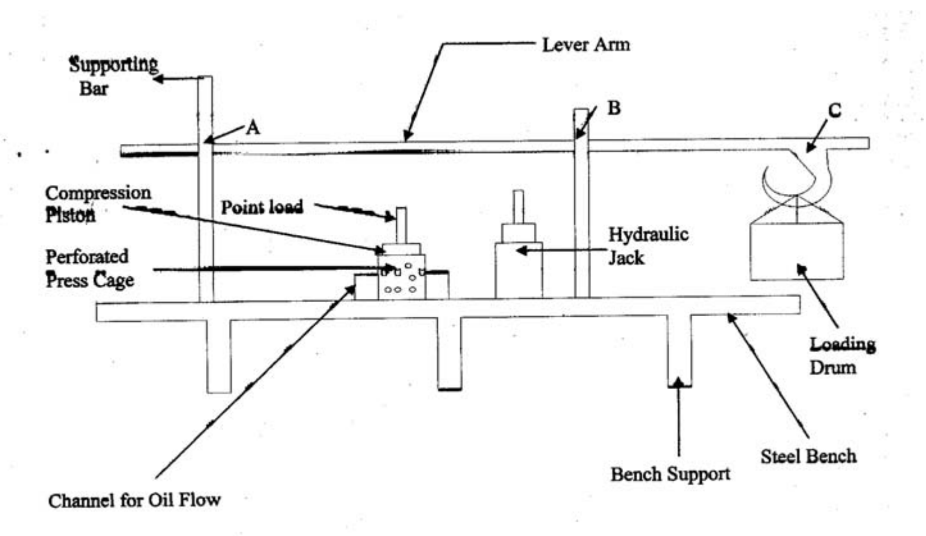

Fig. 1. Schematic diagram of the laboratory press used for the study.

T a b l e 2. Oil yield at different levels of processing operation (%)

Cage diameter (mm)	Pore size (mm)	Pressure (MPa)		
		0.5	1.0	1.5
80	4	18.571	25.352	30.282
	6	27.143	30.496	33.571
	10	22.143	29.286	28.873
120	4	30.147	31.273	30.667
	6	32.593	34.237	37.333
	10	32.000	33.559	35.000
150	4	18.615	19.523	20.346
	6	20.346	24.459	25.054
	10	18.872	23.210	24.026

T a b l e 3. Volumetric flow rate ($m^3 s^{-1}$)

Cage diameter (mm)	Pore size (mm)	Pressure (MPa)		
		0.5	1.0	1.5
80	4	4.867×10^{-7}	62.500×10^{-7}	7.333×10^{-7}
	6	5.733×10^{-7}	7.833×10^{-7}	8.000×10^{-7}
	10	5.400×10^{-7}	7.233×10^{-7}	7.067×10^{-7}
120	4	15.28×10^{-7}	16.25×10^{-7}	17.22×10^{-7}
	6	16.48×10^{-7}	19.88×10^{-7}	20.63×10^{-7}
	10	16.43×10^{-7}	18.78×10^{-7}	18.77×10^{-7}
150	4	16.12×10^{-7}	16.83×10^{-7}	17.40×10^{-7}
	6	17.43×10^{-7}	20.70×10^{-7}	21.35×10^{-7}
	10	16.35×10^{-7}	19.32×10^{-7}	20.46×10^{-7}

T a b l e 4. Superficial flow rate ($m s^{-1}$)

Cage diameter (mm)	Pore size (mm)	Pressure (MPa)		
		0.5	1.0	1.5
80	4	6.455×10^{-4}	8.289×10^{-4}	9.725×10^{-4}
	6	3.379×10^{-4}	4.617×10^{-4}	4.715×10^{-4}
	10	2.218×10^{-4}	2.970×10^{-4}	7.067×10^{-4}
120	4	12.790×10^{-4}	13.610×10^{-4}	14.420×10^{-4}
	6	6.475×10^{-4}	7.811×10^{-4}	8.106×10^{-4}
	10	4.648×10^{-4}	5.313×10^{-4}	5.310×10^{-4}
150	4	11.150×10^{-4}	11.640×10^{-4}	12.040×10^{-4}
	6	5.359×10^{-4}	6.365×10^{-4}	8.389×10^{-4}
	10	3.589×10^{-4}	4.241×10^{-4}	5.268×10^{-4}

Figure 2 shows the effect of pore size on oil yield. Oil yield was observed to increase with increase in pore size from 4 to 6 mm. The increase in oil yield with pore size in this range could be attributed to the fact that the larger the pore the less restriction to flow and the more oil that can flow through the pore space (based on fluid flow principle - Bird *et al*., 2002). However, oil yield was observed to drop with increase in pore size form 6 to 10 mm. This may be due to the fact that the wall pore appeared bigger and hence could not sieve the digested particles, thereby causing the fibrous materials to block the passage. This automatically reduced the quantity of oil collected. The explanation of the effect of pore size in this regard can be extended to the effect of increase in porosity which increases the permeability of fluid. This has been reported by many authors (Schwartzberg, 1997; Kamst *et al*., 19970).

The effect of cage diameter on yield of oil is shown in Fig. 3. Oil yield was observed to increase with increase in

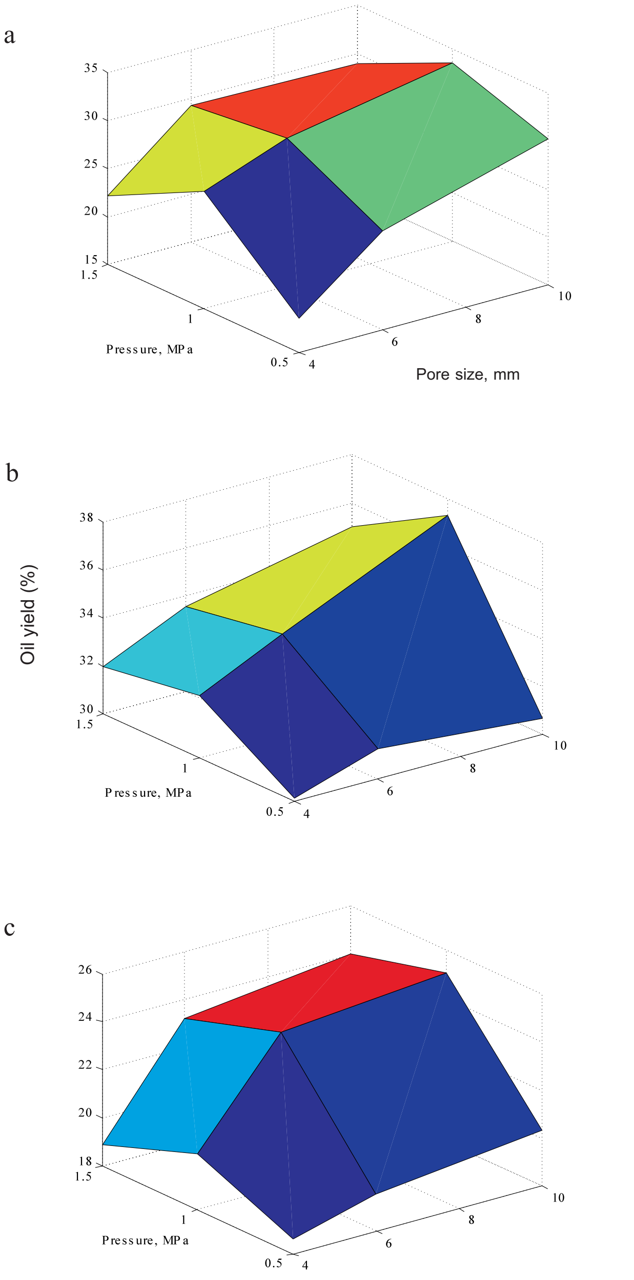

Fig. 2. Effect of pore size and pressure on oil yield from: a – 80, b – 120, and c – 150 mm diameter cage.

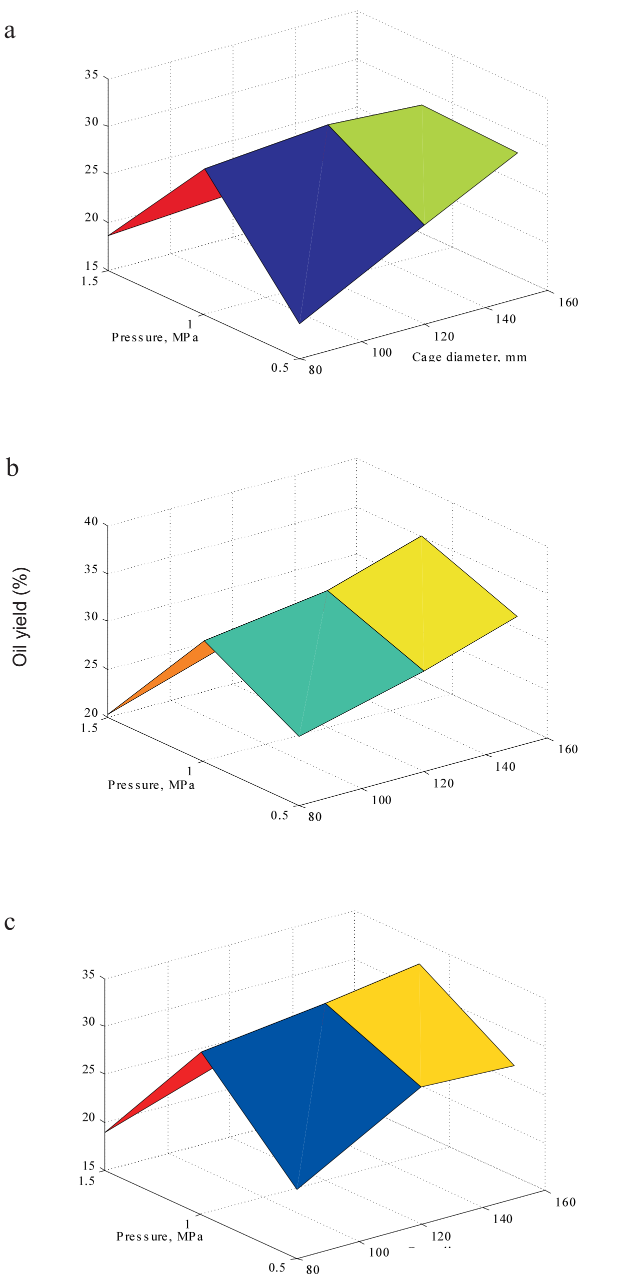

Fig. 3. Effect of cage diameter and pressure on oil yield from: a – 4, b – 6, and c – 10 mm pore sizes.

cage diameter from 80 to 120 mm. This result can be attributed to the fact that with increase in cage diameter there is more material in the cage and hence more oil is expected. Increasing the cage diameter from 120 to 150 mm, however, reduced the quantity of oil obtained. This trend may be due to the probable radial reduction of flow velocity as emanated from the reduction of the fluid pressure as it travels towards the wall cage. This is in agreement with the findings of Stork (1961) on hydraulic press. Stork (1961) observed that the cake nearer to the wall of the palm oil press cage appears wetter when compared with the one at the centre. Stork (1961) explained further that the pressure profile may be assumed to be parabolic in nature, with the highest point being in the centre. Singh and Singh (1991) also reported similar findings on rapeseed. The effective pressure was observed to change with the radial distance during uniaxial compression of rapeseed in a hydraulic press.

A close observation of Figs 2 and 3 reveals that increase in pressure increased oil yield at every pore size and cage diameter. This is in agreement with earlier results obtained by Baryeh (2001) and Vadke and Solsulki (1988). Baryeh (2001) observed that palm oil yield increased from 2 to 53% with increase in applied pressure form 5 to 35 Mn m^{-2}. Also reduction of choke opening of screw press (analogous to increase in pressure) has been observed to increase canola oil yield (Vadke and Solsulki, 1988). Researchers on other oil bearing material (oilseeds) have reported increase in oil yield with pressure. Fasina and Ajibola (1989) and Adeeko and Ajibola (1990) observed that oil yield from conophor (*Tetracarpidium conophorum*) and groundnut, respectively, increased with increase in pressure from 10 to 25 MPa.

The statistical analysis (SAS, 1987) of the effect of processing factors on oil yield indicates that all the factors (cage diameter, pore size and expression pressure) are significant at 99%. The oil yield was observed to be represented by:

$$Y=27.76-0.07D+0.33H+5.82P,$$

where: Y – oil yield, D – cage diameter, H – pore size, P – pressure, (R^2 = 90.9%).

The trend of the effects of pore size, cage diameter and expression pressure on volumetric flow of oil and superficial flow are similar with that of oil yield as shown in Figs 4-6, respectively. This is expected, since the volume of oil has a relationship with the weight of oil. Increased volumetric oil flow with pressure, as observed in this study, has also been reported by Fasina and Ajibola (1989) on expression of oil from conophor (*Tetracarpidium conophorum*). Furhermore, Huang (1979) observed that superficial flow of fluid from spent drip coffee ground increased with increase in ram speed (increase in pressure) from 1 to 20 cm min^{-1}.

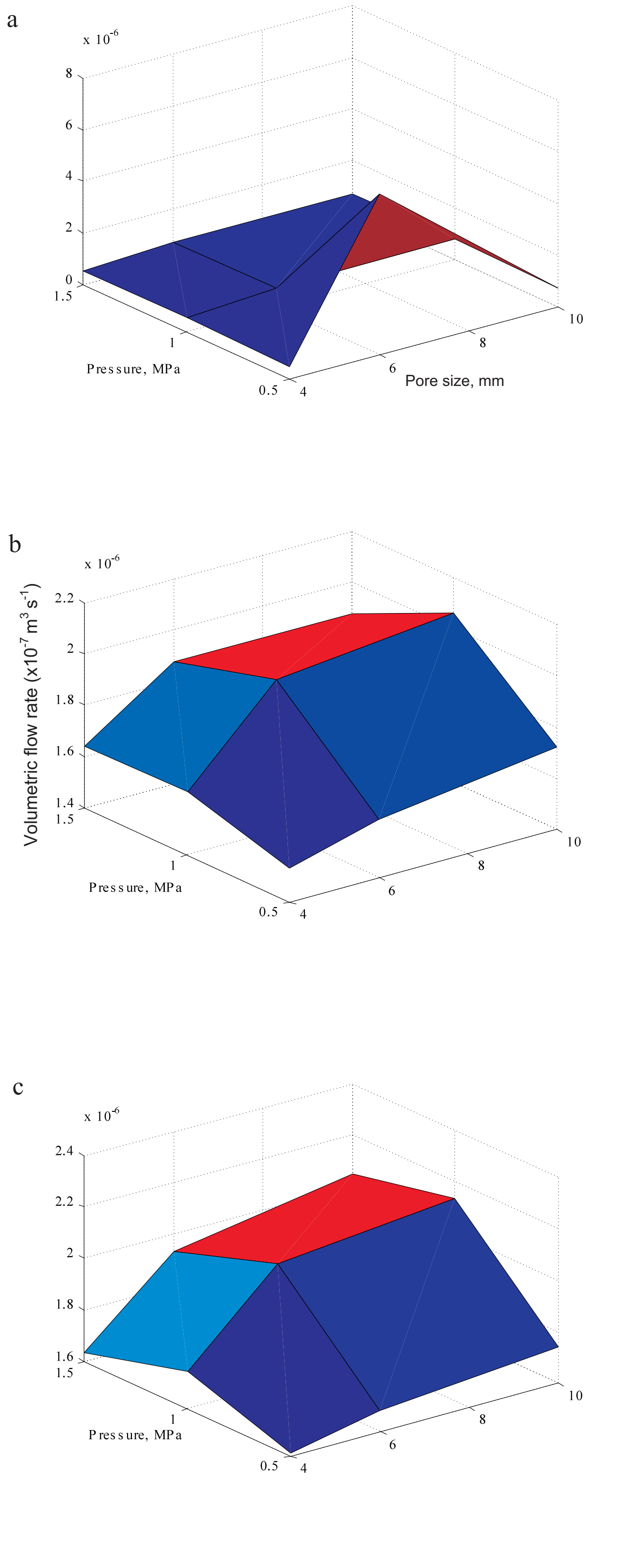

Fig. 4. Effect of pore size and pressure on volumetric flow rate from: a – 80, b – 120, and c – 150 mm diameter cage.

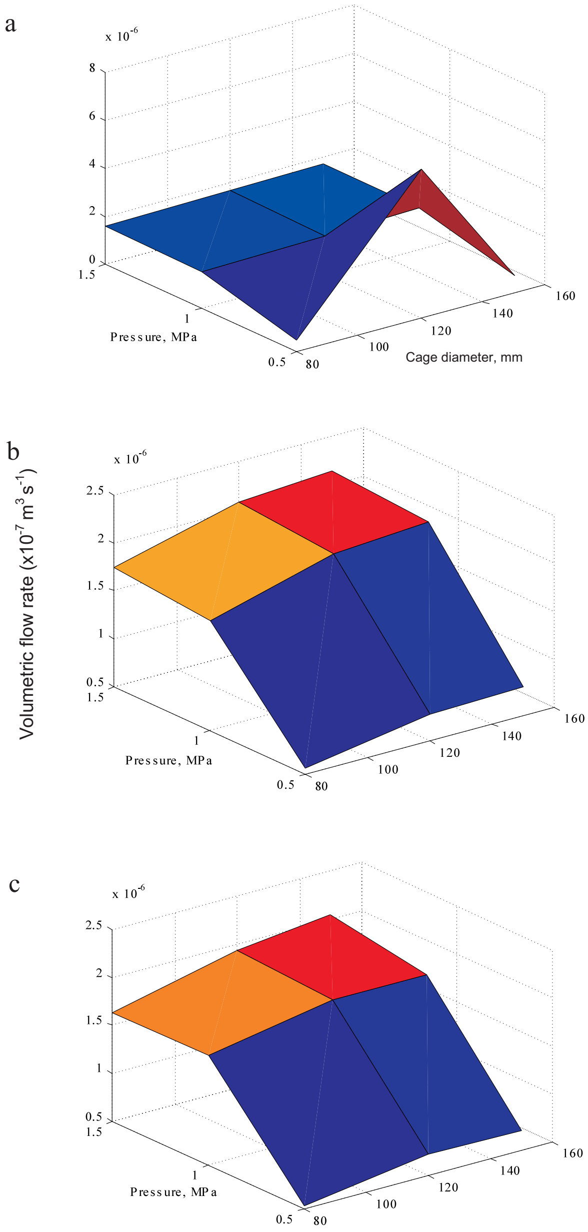

Fig. 5. Effect of cage diameter and pressure on oil yield from: a – 4, b – 6, and c – 10 mm pore sizes.

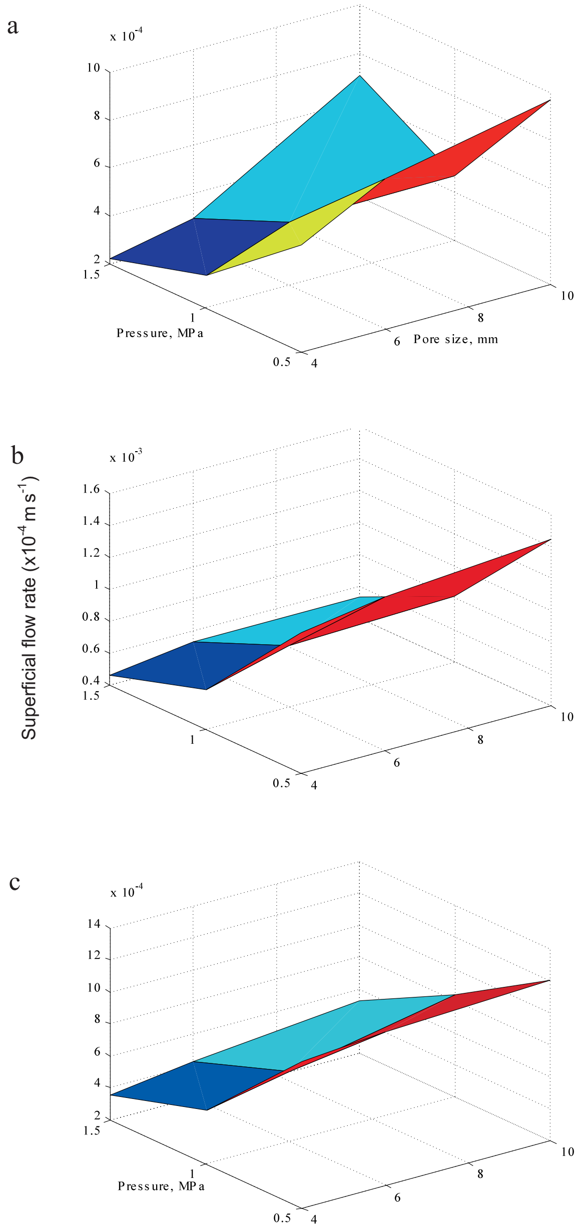

Fig. 6. Effect of pore size and pressure on superficial flow rate from: a – 80, b – 120, and c – 150 mm diameter cage.

CONCLUSIONS

1. It was found that there is a limit to which the pore size and cage diameter of an hydraulic press can be increased to increase oil yield and readily flow of oil.

2. The study hence provides data toward optimal design of press.

3. The empirical equation developed will also be useful in this respect.

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