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OIL SEED PROCESSING TECHNOLOGY IN PAKISTAN
Part -IX. Evaluation of Differently Designed Screw Assemblies in Small Expeller

DIN MUHAMMAD AND SHAFIQ AHMAD KHAN*

PCSIR Laboratories Complex, Lahore-54600, Pakistan

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A number of screw configurations, with successive increasing compression ratio, were designed and tested to optimize for use in the newly developed expeller model-3. Experiments were conducted on designed screw configuration using rapeseed as a raw material. The experimental data, its analysis and the design features and the performance of screw configurations are discussed to determine the best performing screw configuration

Key words: Screw configuration, Helical grooves, Processing capacity gash space.

Introduction

History of the technology. The extraction of oil from plant sources, in particular from mustard and rapeseed, has been a traditional craft in Pakistan. The technology progressed during 60's and 70's from the common animal (Fig. 1) or power driven Kohlu (Fig. 2) to small screw expeller. Small expeller, initially a copy of the Japanese Hander Expeller (Fig. 3), was not welll adjusted in the local conditions. A locally designed small expeller, called Lahore expeller (Fig. 4) was then introduced and it was virtually a copy of the old Anderson Expeller [1].

The oilseed technology group at the Lahore Laboratories of PCSIR initiated R&D work on small expeller under the Village Level Food Processing Project supported by USAID from 1978 to 1981. As a result a base line survey of the existing oilseed processing technology was carried out, the collected data was compared and the most promising candidate technology was selected for further development. Consequently a small expeller (Fig. 5) called model No. 1 (chamber length 11") was developed which is presently performing better than the old design in the rural areas [2-4].

The International Development Research Centre (IDRC), Canada provided financial support for the project with the objective of not only up-grading and further disseminating the previously modified expeller model No. 1 but also to incorporate changes for better performance. In this respect 2 expellers Model Nos. 2 & 3 with extended cages 16" and 22" respectively have been developed (Figs. 6&7) [4 - 6]. The R&D effort was directed towards optimising the screw configuration in the small expeller Model No. 3 since the screw has the basic importance as it determines the performance efficiency.

Problems. Literature survey revealed that there is scantly information describing the effect of specific configurations. Most work appears to have been done by manufacturing companies using imperical approach [7]. A more rigorous scientific approach was thus required to predict more accurately, the results of a particular worm configuration design. It was therefore, decided to analyse the performance of various designed screw configurations as a first step in a scientific manner for making further improvements.

Some of the major problems of the old modified screw design were unsmooth operation, oiling up, heavy foots, high oil in cake, high maintenance cost, heavy power consumption and its unsuitability for hard oilseeds. Removal/minimising of these problems through R&D was thus initiated with a view to (i) having the best possible screw configuration for a given oilseed, (ii) consuming less power supply, (iii) upgrading its capabilities for the processing of hard oilseed, (such as sunflowers, safflower, soybean and cottonseed) and providing maximum benefits to small millers particularly in the rural areas.

Screw design. The original screw configuration of expeller Model No. 3 consisted of 7 worm sections including one reverse worm in the 6th position and its description is provided in Table 1 [8].

The screw sections were arranged on screw assembly in pitch decreasing order successively starting from the feed

TABLE 1. ORIGINAL SCREW CONFIGURATION; REVERSE WORM (6TH WORM).

No. of worm Sections	= 1	2	3	4	5	6	7
Length of worm (cm +)	= 16.5	10.16	7.62	6.35	5.71	5.08	4.44
Pitch of worm	= 12.7	10.16	7.62	6.35	5.71	5.08	4.44
Screw hub-dia	= Constant diameter i.e. 6.8 cm.						
Spacers	= Starting from 2nd worm: 1.59 cm spacer between each worm.						

*Present Address: Pakistan Council for Science & Technology, Islamabad.

towards discharge ends, keeping hub-diameter constant. The compression ratio of the original configuration was around 1:3.5. Therefore, the new screw configurations with higher compression ratios were investigated particularly in expeller model No. 3. The new configurations comprised of increased hub-diameter, reduced pitch, reduced or eliminated gash, original configuration with short pitched (2.5 cm) feed worm, feed worm raised flight with 2 reverse worms. The screw configurations are summarised as under:

(a) Tapered screw: Reducing the free space between cage and screw hub by 50% and 75% respectively, starting from the 3rd worm.

(b) Pitch reducing screws:

(i). 12.7 10.16 7.62 5.08 4.45 3.81 3.81

(ii) 12.7 10.16 7.62 5.08 3.81 3.2 3.2

(c) Original configuration with eliminated gash.

(d) Original configuration with short pitched (2.5 cm) feed worm.

(e) Feed worm raised flight with 2 reverse worms of variable flight height.

Materials and Methods

Screw press model No. 3 was used for investigating the above mentioned screw configurations. The expeller was operated at 57 and 37 rpm., driven by 15 H.P. and 10. H.P. (3 phase), 440 Volts electric motors respectively. The other parameters, oilseeds (rapeseeds), batch size (20 kg.), seed pre-treatment and thickness of cake (4 mm) were kept constant for all the experiments. The experimental results are the mean values of at least three experiments on each screw configuration.

The final screw configuration was then tested on hard

TABLE 2. A COMPARISON OF DIFFERENT SCREW CONFIGURATIONS.

Exp. No.	Water added to seed	Driving H.P.	RPM of screw shaft	Oil yield (kg)/(Extraction efficiency%) pressing cycle				Energy consumption : Wh/kg seed and Wh/kg oil/pressing cycle			
A	B	C	D	1	2	3	4	1	2	3	4
1.	no	15	57	3.5/40.3	2.6/70.2	0.9/80.6	0.65/88.3	25/143	50/164	75/215	110/288
2.	400ml	15	57	4.0/46.0	2.9/79.1	1.0/90.4	–	31/15	60/175	96/244	–
3.	no	15	57	1.1/13.3	1.7/33.4	1.6/55.3	1.7/75.4	23/402	39/273	54/230	73/228
4.	400 ml	15	57	2.9/33.7	2.9/67.9	1.0/78.7	0.4/83.4	30/211	50/197	94/288	131/372
5.	400 ml	15	57	....	....	....	No result	....	....	....	....
6.	400 ml	15	57	2.0/23.7	0.7/31.9	1.1/45.0	1.1/57.9	29/290	40/293	57/297	69/282
7.	no	10	37	....	....	....	No result	....	....	....	....
8.	400 ml	15	57	3.0/34.5	2.5/63.4	1.2/77.2	0.4/81.8	28/183	68/246	110/128	179/502
9.	no	10	37	....	....	....	No result	....	....	....	....
10.	no	10	37	5.7/65.7	1.4/81.8	0.8/91.0	–	34/119	62/173	90/225	–
11.	no	10	37	5.5/61.6	1.75/81.8	0.8/91.0	–	31/114	53/149	76/189	–
12.	no	10	37	5.1/58.8	1.7/78.3	0.9/88.7	–	30/118	30/118	68/175	–
13.	no	10	37	4.85/55.9	1.6/74.3	1.2/88.1	–	24/99	24/99	58/152	–
14.	800 ml	10	37	5.5/68.8	1.6/88.8	–	–	46/166	46/166	–	–
15.	1 litre	10	37	3.8/64.8	1.0/81.9	–	–	57/300	57/300	–	–
16	no	10	37	2.75/65.2	–	–	–	51/371	51/371	–	–

Last cycle	Results after last pressing cycle: Res. oil content	Total yield	Extract efficient	Capacity	Total energy consumption Wh/kg seed/Wh/kg oil	Exp. No.
4.	8.4	7.65	88.4	80.0	110/188	1
3.	7.0	7.85	90.4	78.5	96/244	2
5.	9.6	7.22	85.4	56.8	95/263	3
	10.8	7.05	83.4	43.4	131/372	4
7.	12.6	6.8	80.4	42.7	111/327	6
5.	10.16	7.4	85.3	27.0	167/450	8
3.	6.44	7.9	91.0	98.0	90/288	10
3.	6.44	7.9	91.0	109.0	75/189	11
3.	7.79	7.77	88.7	109.0	68/175	12
3.	8.34	7.65	88.1	109.0	58/152	13
2.	7.0	7.1	88.8	100.0	81/227	14
	7.0	4.8	81.0	100.0	112/467	15
1.	8.5	2.75	65.2	120.0	51/371	16

oilseeds such as sunflower, safflower and cottonseeds.

Data on oil yield per pressing cycle, extraction efficiency, energy consumption (both Wh/kg. seed and Wh/kg. oil), residual oil content and capacity is summarized under Table 2 and their graphic representations is also provided.

Results and Discussions

The original screw configuration contained 1 reverse worm in the 6th (2nd last) position. The oil extraction rate was much higher in the presence of the reverse worm. The configuration allowed a smooth operation and pressed to a residual oil content of 8-9% in 4 cycles (Experimental results No. 1; Graph-1). The expeller was driven by 15 H.P. 3 phase electric motor.

The function of the reverse worm was visualised. It was, therefore, concluded that a small gap between the end of the flight of the 5th worm and the reverse worm, through which the material has to be forced, was of critical importance. The size of the gap could be modified by inserting spacers between the 5th and the reverse worm. This gap effectively determined the theoretical compression ratio in the configuration round 1:20.

The compression ratio of the next configuration was increased more than the original configuration by reducing the hub-diameter from 6.9 cm to 5.8 cm (Fig. 8). This increased the theoretical feed volume by about 24%. The expeller operated very smoothly with this worm set and an extraction yield of 90.4% was achieved in only 3 passes (Exp. result No. 2; Graph 2), but the energy consumption (96 Wh/kg. seed) was high as compared to the foreign expeller i.e. 75 Wh/kg.

The gradual reduction of the free space between screw and cage (50% and 75% respectively; (Fig. 9 and 10) did not result in the expected improvements (Exp. results No. 3 and 4; Graphs 3-4). The necessary pressure could not be generated by the poor function of the feed worm and consequently pressing efficiency was considerably reduced as compared with the original configuration.

The pitch reduced configuration was also not successful in pressing oilseeds because of lock-up of the material in the short pitched worms (Exp. result No. 5) and the high feeding and reduced discharged of material by the use of short pitched discharge worms at the end of screw configuration.

The effect of reducing or eliminating the gash completely was also investigated. The modification did not result in any improved performance (Experiment No. 6 ; Graph 5). The operation was not smooth due to occassional lock-up of the material. It was experienced that gash elimination stopped the balancing of the pressure inside the cage. Probably this was the reason of producing negative results.

It is known from the literature that small expellers of European and American origin use feed screws of a very short pitch, generally only about 2.5 cm [9]. This reduces the theoretical transport volume of the feed screw, but as the component force causing rotation is much smaller the feeding efficiency is considerably high. Therefore, short pitched screw configuration (Fig. 11) was tested (Exp. No. 7). It failed to function due to very small space for the intake of material on the modified feed worm. The shape of the configuration of screw thread also hindered the flow of material through the cage and therefore, no experimental data could be obtained.

The experiments were however, continued by increasing the pitch of the 2nd feed worm from 2.5 cm to 3.8 cm. (Fig. 12). The experimental results indicated decreased efficiency of the configuration (Exp. results No. 8; Graph 7). The short pitched configuration, under the present experimental conditions failed to provide improved results.

The short pitched configuration may yet work under other conditions such as making U-shaped instead of helical grooves over it, so that comparatively more volume of seeds could be taken between the flights space, tapering the screw shaft and operating the expeller at higher rpm as capacity of a configuration is also dependent on the rpm of the main shaft. Further R&D work on this configuration may lead towards some more interesting results, such as squeezing oil from oil bearing materials in a single pass that would help in saving labour and simplifying the processing operation.

Some more screw configurations were also tested which consisted of modified feed worms coupled with 2 reverse worms and operated at lower rpm (37 instead of 57 as was in the original configuration).

The feed worm was modified by raising its flight from 1.43 cm to 2.1 cm. The feed worm normally entered in the cage to a length of 5.1 cm that was made hollow by tapering the cage bars, so that the feed worm could rotate in conical form inside the cage.

The function of a reverse worm was carefully examined and it was learnt that the magnitude of back pressure was dependent on its length, shoulder-height, gash space and the space used before the reverse worm.

Since 2 reverse worms were used in the present configurations, therefore, their flight-heights were decreaced from 1.27 cm to 0.635 cm successively, and gash was widened from 2.54 cm to 5.1 cm in order to allow more space for the over flow of material over them.

The rpm of the main screw shaft were decreased from 57 to 37 and operated by 10 h.p. electric motor instead of 15 H.P. electric motor.

When the shoulder height of reverse worm was kept at 1.27 cm (Exp. 9), the configuration did not produce any results. One reason for this situation was that the space for the over flow of material was small and therefore, feeding was hindered.

In another experiment the shoulder-height of reverse worms was lowered to 1.111 cm (Exp. No. 10). This configuration also caused some feeding problems initially. The expeller was, however, operated for few hours with hard cake in order to polish its screw parts. After polishing the configuration worked smoothly. The capacity worked out to be 98 kg/hr. with an exraction yield of 91.0% in 3 passes. The energy consumption was about the same (90 Wh/kg) as in the original configuration. The results of this configuration are graphically represented in Graph 7.

The open space, over the reverse worms, was slightly increased by decreasing the shoulder-height from 1.111 to 0.953 cm (Fig. 13). This changed condition improved the performance of the configuration to a large extent. The expeller operated very smoothly and processing capacity increased to 109 kg/hr. The oil yield was 91% in 3 passes. The energy consumption was lowered to 75.5 Wh/kg seed as against (96 Wh/kg seed) for the origianl configuration. The major achievements of this configuration are summarized below:-

(a) It provided a very smooth operation, (b) Processing capacity increased to 109 kg/hr as compared to 83 kg/hr. for the original configuration, (c) Energy consumption reduced/lowered to 75.5 Wh/kg seed, which is equivalent to the European expeller, (d) Initial driving force decreased to 10 H.P. instead of 15 H.P. electric motor.

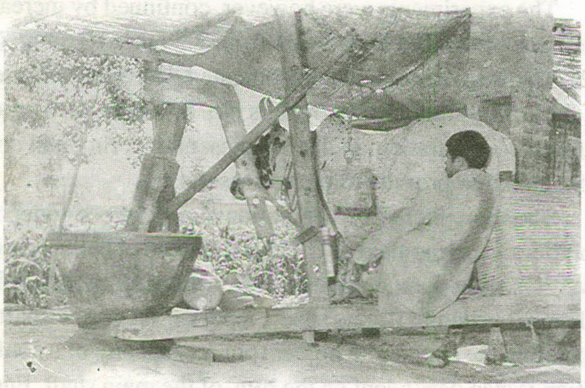


Fig. 1. Animal driven Kohlu.

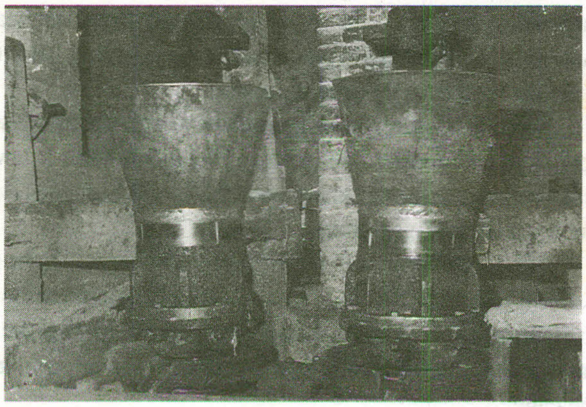


Fig. 2. Power driven Kohlu.

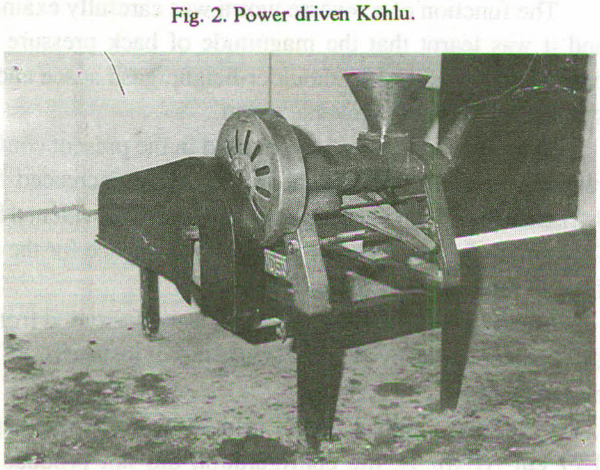


Fig. 3. Japanese hander expeller H-52.

Fig. 4. Lahore expeller.

Fig. 5. Modified expeller model No.1.

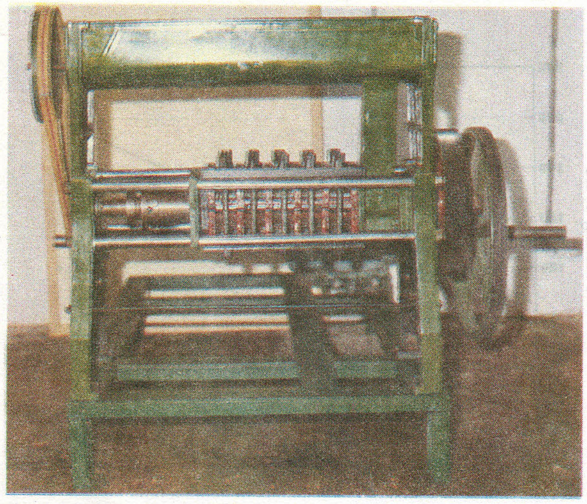


Fig. 6. Modified expeller model No. 2.

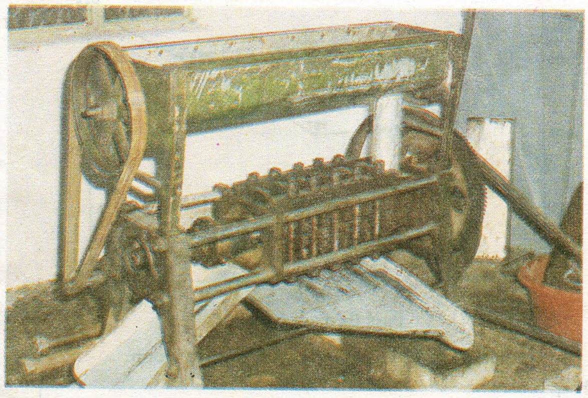


Fig. 7. Modified expeller model No. 3.

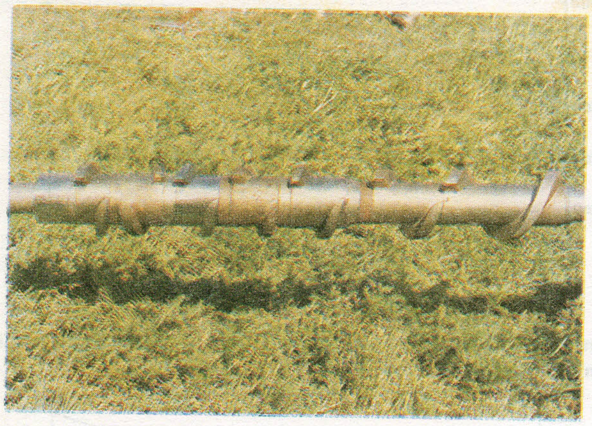


Fig. 8. Reduced hub-dia screw configuration.

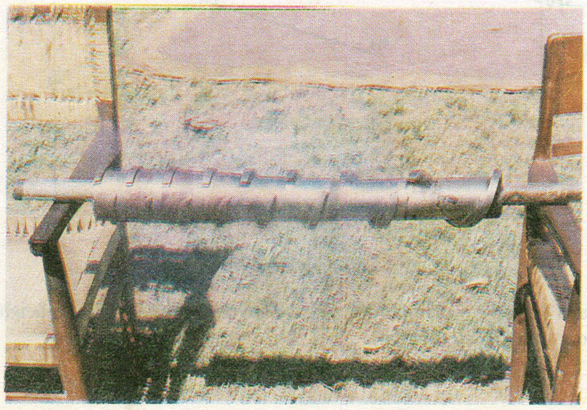


Fig. 9. Gradual reduction of free space between screw and cage (50%).

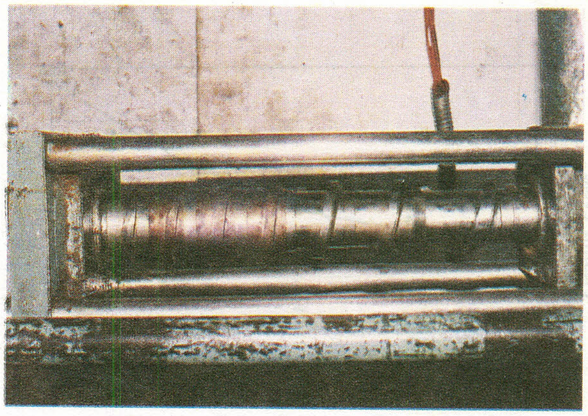


Fig. 10. Gradual reduction (75%) of free space between screw and cage

Fig. 11. Short pitched screw configuration.

Fig. 12. Short pitched (3.8 cm) screw configuration.

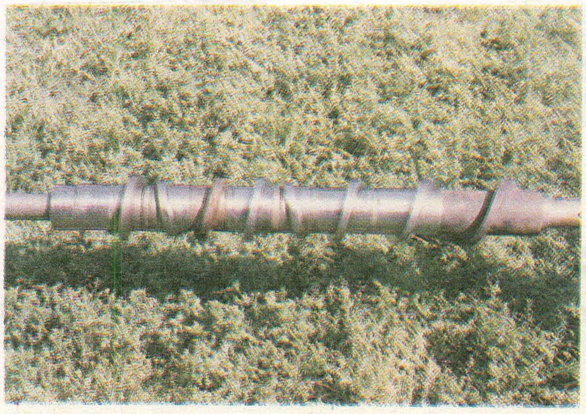
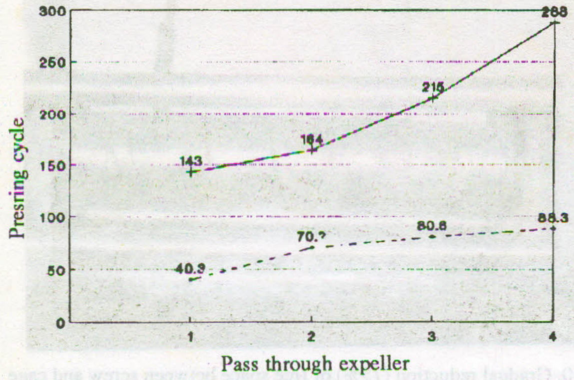
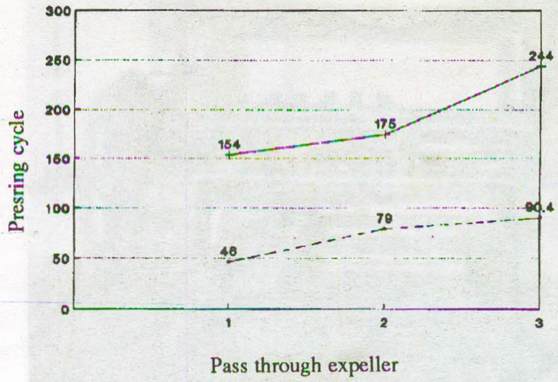


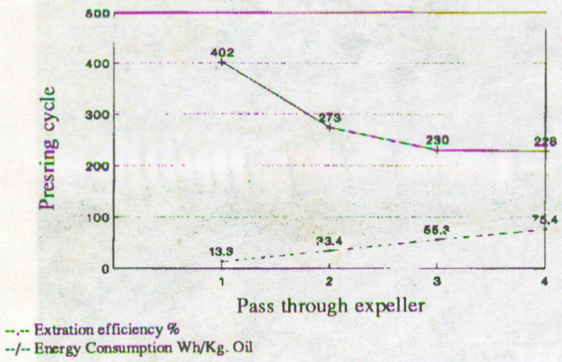
Fig. 13. Final screw configuration with 2 reverse worms.



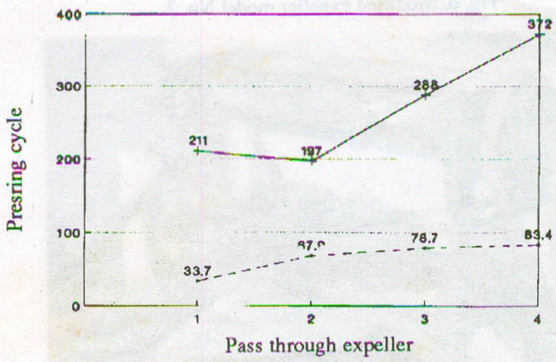
Graph 1. Original screw configuration



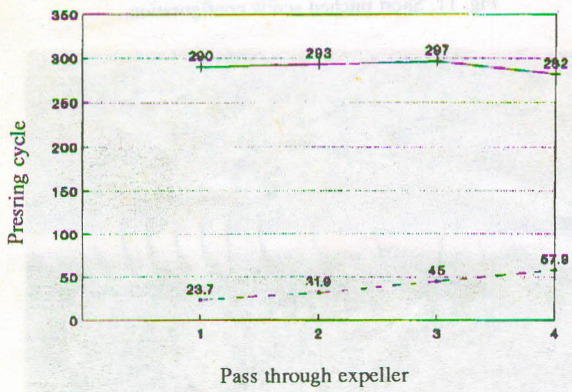
Graph 2. Reduced feed screw diameter configuration.



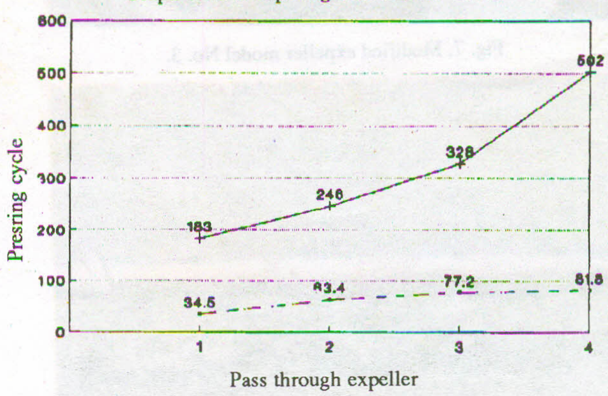
Graph 3. 50% Tapering with reverse worm.



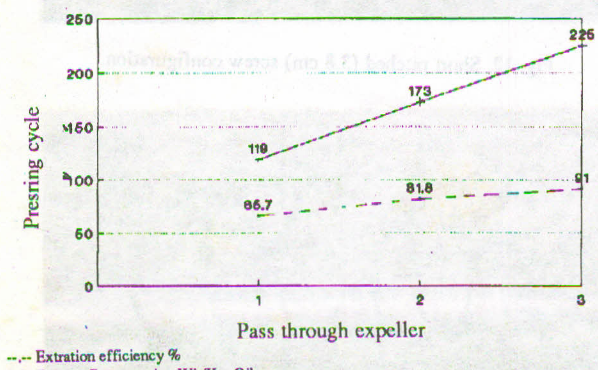
Graph 4. 75% Tapering with reverse worm.



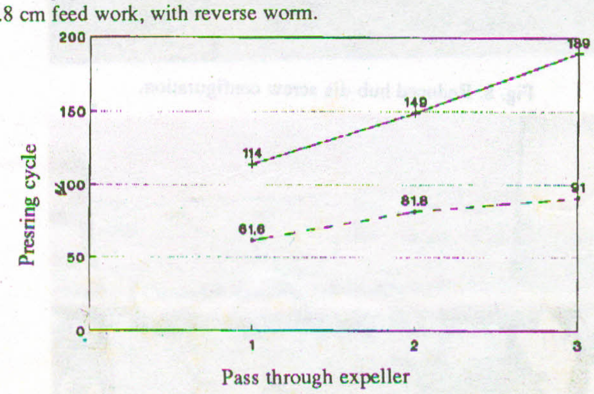
Graph 5. Gash reduction with reverse worm.



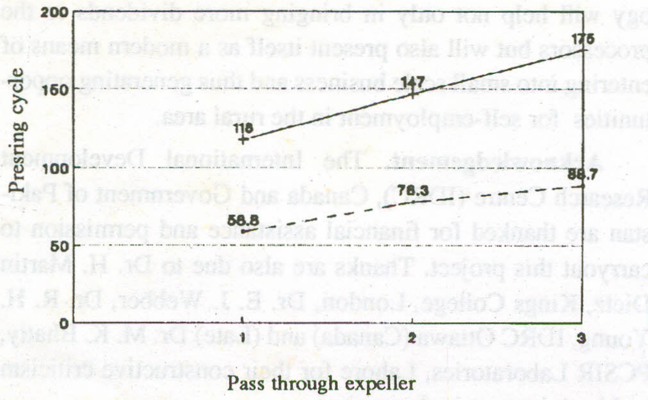
Graph 6. Original feed worm shortened 50% followed 19.1, pitched 3.8 cm feed work, with reverse worm.



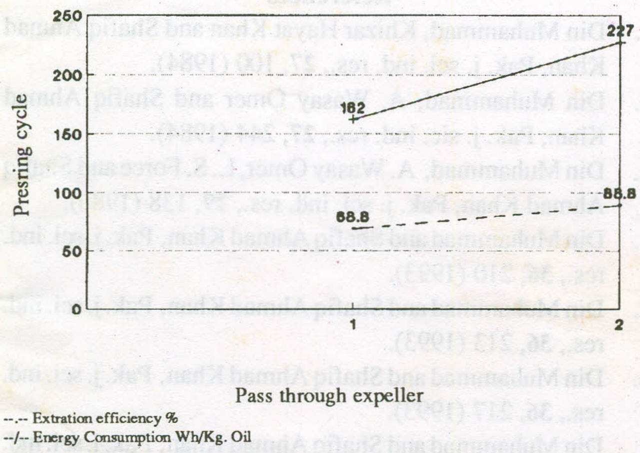
Graph 7. Feed worm improved with two reverse worms (shoulder-height 1.111 cm).



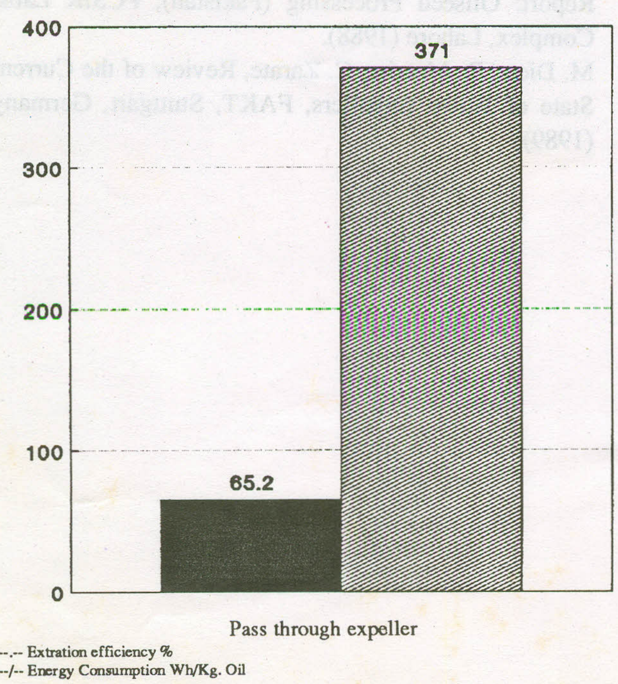
Graph 8. Feed worm improved with two reverse worms (shoulder-height 0.953 cm) (final configuration).



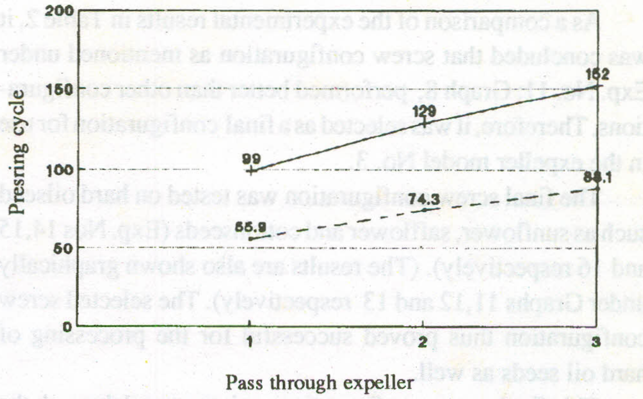
Graph 9. Feed worm improved with two reverse worms (shoulder-height 0.794 cm).



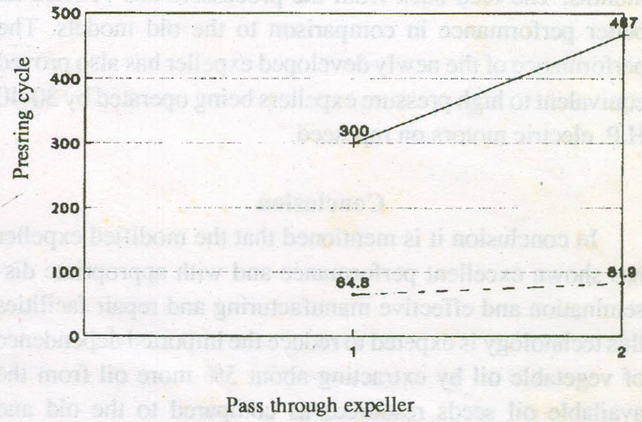
Graph 11. Final configuration on sunflower (Undecort.).



Graph 13. Final configuration on cottonseed (Undecort.)



Graph 10. Feed worm improved with two reverse worms (shoulder-height 0.635 cm).



Graph 12. Final configuration on safflower (Undecort.)

The component force of rotation in the present configuration was minimized by increasing the component force of axial push by the action of 2 reverse worms and also operating at low rpm (37). The open space over the reverse worm was optimized for the over flow of material which resulted in smooth operation of the expeller. These measures, when adopted, were helpful in saving the energy losses and increasing the over all performance of the expeller.

The shoulder-height of reverse worm was further reduced to 0.794 cm. This configuration provided relatively a very smooth operation. The processing capacity was the same as described above (109 kg/hr.) while the oil yield decreased to 88.7% from 91% in 3 passes. The energy consumption was, however, lowered (67.5 Wh/kg seed and 175.3 Wh/kg oil) Exp. No. 12, Graph 9.

The shoulder-height of the reverse worm was further decreased to 0.635 cm. This configuration also resulted relatively in a very smooth operation. The capacity (109 kg/hr.) remained the same as in the above case. The oil yield fell to 88.1% in three passes. It was interesting to note that energy consumption was further lowered to 58 Wh/kg seed and 152 Wh/kg oil (Exp. 13, Graph 10).

As a comparison of the experimental results in Table 2, it was concluded that screw configuration as mentioned under Exp. No. 11; Graph 8, performed better than other configurations. Therefore, it was selected as a final configuration for use in the expeller model No. 3.

The final screw configuration was tested on hard oilseed such as sunflower, safflower and cottonseeds (Exp. Nos 14,15 and 16 respectively). (The results are also shown graphically under Graphs 11,12 and 13 respectively). The selected screw configuration thus proved successful for the processing of hard oil seeds as well.

This final screw configuration, as it emerged through the R&D work in the pilot plant, was field tested for more than 6 months. The feed-back from the processors has verified its better performance in comparison to the old models. The performance of the newly developed expeller has also proved equivalent to high pressure expellers being operated by 30-40 H.P. electric motors on rapeseed.

Conclusion

In conclusion it is mentioned that the modified expeller has shown excellent performance and with appropriate dissemination and effective manufacturing and repair facilities this technology is expeted to reduce the imported dependence of vegetable oil by extracting about 5% more oil from the available oil seeds resources as compared to the old and unmodified expeller. It can easily replace the old oil expelling system not only in the country, but also abroad, when produced on a large scale, with standard specifications. It will also have excellent export potential particularly in Africa, North America as well as Asia. In its present form the technology can be installed at a relatively low cost of about rupees 30 thousand. Because of these attractions/benefits this technology will help not only in bringing more dividends to the processors but will also present itself as a modern means of entering into small scale business and thus generating opportunities for self-employment in the rural area.

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