

DESIGN AND DEVELOPMENT OF UNIT FOR EXTRACTING WHEAT GERM OIL

By

ABDEL-GAWAD MOHAMMED ABDEL-GAWAD SAAD

B.Sc. Agric. Sc. (Agric. Eng.), Menoufia University, 2000.

M.Sc. Agric. Sc. (Agric. Eng.), Menoufia University, 2006.

**A thesis submitted in partial fulfillment
of
the requirements for the degree of**

DOCTOR OF PHILOSOPHY

in

**Agricultural Sciences
(Agricultural Mechanization)**

**Department of Agricultural Engineering
Faculty of Agriculture
Ain Shams University**

2012

Approval Sheet

**DESIGN AND DEVELOPMENT OF UNIT FOR
EXTRACTING WHEAT GERM OIL**

By

ABDEL-GAWAD MOHAMMED ABDEL-GAWAD SAAD

B.Sc. Agric. Sc. (Agricultural Engineering), Menoufiya University, 2000.

M.Sc. Agric. Sc. (Agricultural Engineering), Menoufiya University, 2006

This Thesis for Ph.D. degree has been approved by:

Dr. Ahmed El-Raie Emam Suliman

Prof. of Agricultural Engineering, Faculty of Agriculture, Cairo
University.

Dr. Gamal Abdel-Tawab Abo-Ella El-Shatanovi

Prof. of Food Science, Faculty of Agriculture, Ain Shams University

Dr. Mahmoud Ahmed El-Nono

Associate Prof. of Agricultural Engineering, Faculty of Agriculture,
Ain Shams University.

Dr. Mubarak Mohamed Mostafa

Prof. Emeritus of Agricultural Engineering, Faculty of Agriculture,
Ain Shams University

Date of Examination: / /2012.

DESIGN AND DEVELOPMENT OF UNIT FOR EXTRACTING WHEAT GERM OIL

By

ABDEL-GAWAD MOHAMMED ABDEL-GAWAD SAAD

B.Sc. Agric. Sc. (Agricultural Engineering), Menoufiya University, 2000.

M.Sc. Agric. Sc. (Agricultural Engineering), Menoufiya University, 2006

Under the supervision of:

Dr. Mubarak Mohamed Mostafa

Prof. Emeritus of Agricultural Engineering, Department of
Agricultural Engineering, Faculty of Agriculture, Ain Shams
University. (Principal Supervisor)

Dr. Mahmoud Ahmed El-Nono

Associate Prof. of Agricultural Engineering, Department of
Agricultural Engineering, Faculty of Agriculture, Ain Shams
University.

Dr. Taher Rashad Owies

Senior Researcher of Agricultural Engineering, Agricultural
Engineering Research Institute (AEnRI).

ABSTRACT

Abdel-gawad Mohammed Abdel-gawad Saad: Design and Development of Unit for Extracting Wheat Germ Oil. Unpublished Ph.D. Thesis. Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, 2012.

An expelling machine for extracting oil from wheat germ was designed and fabricated to be suitable for young investors. The procedures include the design stages, construction and testing. The main machine components are: Hopper (feeding inlet); expellant unit and an electric motor. The power is transmitted by means of a set of pulleys; sprockets; V-belt; chain and speed reducer (gear box). The expelling unit consists of two screw expellant shafts with two expellant barrels.

The expelling machine evaluated at five screw speeds (25, 35, 45, 55, and 65 rpm); four levels of press head clearance (0.5, 1, 1.5, and 2 mm); studying influence of the preheating process (in the range of 60-70°C) by the water at different atmospheric steaming periods (0, 10, 20, and 30 min) to change the initial moisture content of raw material (13.2%) to different levels (15.4, 16.2, and 16.8%). and influence of heating stabilization process (9.5% of moisture content) on expelling machine performance to determine the best Machine capacity (kg/h); Oil recovery (%); Residual oil (%); Oil productivity(L/h); Specific energy consumption (kWh/kg_{feed}); and Barrel temperature(°C). also, determine the economic feasibility for developed expelling machine.

Results showed that the expeller could be pressed wheat germ on two stages to give a better performance at as following.

- 1- The maximum machine capacity (42.6 kg/h) was obtained from stabilized wheat germ (9.5% moisture content) at 2mm outlet clearance and 65 rpm of screw speed.
- 2- The maximum oil recovery (63%) was obtained from stabilized wheat germ (9.5% moisture content) at 0.5mm outlet clearance and 25 rpm of screw speed.

- 3- The maximum oil productivity (2.36 L/h) was obtained from stabilized wheat germ (9.5% moisture content) at 2mm outlet clearance and 65 rpm of screw speed.
- 4- The minimum SEC (0.0304 kWh/kg_{feed}) was found from wheat germ (13.2% moisture content) at 2mm outlet clearance and 65 rpm of screw speed.
- 5- The minimum barrel temperature (51.1°C) was found from raw wheat germ (13.2% moisture content) at 2mm outlet clearance and 25 rpm of screw speed.

Keywords: Oil Extraction, Expelling machine Design, Wheat Germ Oil, Economic Feasibility.

ACKNOWLEDGEMENT

First and foremost I would like express my thanks to **Almighty ALLAH** on successful completion of this research work and thesis.

Allah Almighty had been so helpful in his blessings by giving me a prospect to toil under the esteem supervision of **Prof Dr. Mubarak Mohamed Mostafa**, Professor, Agricultural Engineering Dep., Faculty of Agriculture, Ain Shams University. I have no words to express my gratitude for his diligent cooperation, scrupulous support and cheering perspective during the entire degree program.

I deem it my utmost pleasure in expressing my gratitude with the insightful benedictions to **Dr. Mahmoud El-Nono**, Assistant Professor, Agricultural Engineering Dep., Faculty of Agriculture, Ain Shams University. His sympathetic attitude, parental guidance, scholarly suggestions and criticism indeed are incalculable wealth for me.

Thanks are due to **Dr. Taher Rashad Owies**, Senior Researcher, AEnRI, Dokki, for his moral help, and cooperation.

A stanch appreciation to **Dr. Osama Kadour**, Senior Researcher, Agricultural Engineering Research Institute (AEnRI), Dokki, for his cooperation in machine modification and experimental work. I am also grateful to **Dr. Nazeer El-Biale**, Researcher, AEnRI, Dokki, for his brotherly advices and valued suggestions throughout the research project.

Thanks are due to my friend **Eng. Mohamed El-Didamony**, Ass. Researcher, AEnRI, Dokki, for his help, and cooperation

FINALLY, I wish to express my deepest appreciation to my family (spirit of my father), my mother, my wife, and my two children, for their continuous encouragement and support.

Abdel-Gawad Mohammad Saad

CONTENTS

	Page
LIST OF TABLES	v
LIST OF FIGURES	vi
LIST OF SYMBOLS	ix
1. INTRODUCTION	1
2. REVIEW OF LITERATURES	3
2.1. Wheat germ.....	3
2.1.1. Grain Structure.....	4
2.1.2. Germ Recovery.....	5
2.1.3. Physical and mechanical properties of wheat germ	6
2.2. Wheat Germ Oils (WGO)	7
2.2.1. Wheat Germ Oil Content.....	8
2.2.2. Wheat Germ Oil Properties.	9
2.2.3. Fatty Acid Composition	10
2.2.4. The importance of wheat germ oil and uses.	12
2.3. Pretreatment methods for extracting crude oil from wheat germ.	15
2.3.1. Stabilization process.	15
2.3.2. Steaming process.	17
2.4. Oil Extraction.	18
2.4.1. Mechanical Extraction.....	18
2.4.1.1. History and applications.....	18
2.4.1.2. Hydraulic Pressing	20
2.4.1.3. Expeller Extraction.....	21
2.4.1. 4. Advantages and disadvantages of mechanical extraction.....	28
2.4.2. Solvent Extraction	29
2.4.2.1. Advantages and disadvantages of solvent extraction.....	32
2.4.3. Extraction by Supercritical Carbon Dioxide	32
2.5. Energy	34
2.6. Machinery Costs	35
2.6.1. Ownership costs	36
2.6.2. Operating costs	36

3.	THEORETICAL CONSIDERATION	38
3.	Theoretical Detail Design Calculations	38
3.1.	Design of expeller machine	38
3.1.1.	Function	39
3.1.1.1.	Oil flow through cell wall pores.	39
3.1.1.2.	Oil flow in the inter-kernel voids.	40
3.1.1.3.	Consolidation of the oil wheat germ cake.	40
3.2.	Important Design Inputs.	40
3.2.1	Hopper	40
3.2.2	Screw Shaft.	42
3.2.2.1	Screw Parameters	43
3.2.3.	Stress analysis	46
4.	MATERIAL AND METHODS	49
4.1.	MATERIALS	49
4.1.1.	Wheat Germ	49
4.1.2.	Expelling Machine Description	50
4.1.2.1.	Main frame	50
4.1.2.2.	Hopper	52
4.1.2.3.	Barrel (Cage)	52
4.1.2.4.	Screw Shaft	55
4.1.2.5.	Flange	57
4.1.2.6.	Conical choke mechanism for cake drainage.....	58
4.1.2.7.	Power transmission	60
4.2.	DEVICES AND MEASURING INSTRUMENTS	61
4.2.1.	Angle of repose meter	61
4.2.2.	Tachometer	61
4.2.3.	Clamp meter	62
4.2.4.	Drying oven	62
4.2.5.	Infrared thermometer	63
4.2.6.	Heat stabilization unit	63
4.2.7.	Atmospheric steaming unit	64
4.3.	METHODS	65

4.3.1.	Measuring true density, and bulk density of wheat germ	65
4.3.2.	Repose angle of wheat germ	66
4.3.3.	Experimental treatments	66
4.3.3.1.	Atmospheric steaming process	66
4.3.3.2.	Stabilization of wheat germ	67
4.3.4.	Determination of moisture content	67
4.3.5.	Machine capacity (kg feed/h)	68
4.3.6.	Determination of oil recovery (%).....	68
4.3.7.	Determination of residual oil percentage	68
4.3.8.	Oil productivity	69
4.3.9.	Total specific Energy Consumption (SEC)	70
4.3.10.	Barrel temperature	71
4.3.11.	Cost estimation	71
4.3.12.	Economic feasibility.....	72
5.	RESULTS AND DISCUSSION	73
5.1.	Effect of atmospheric steaming process for wheat germ on machine capacity (kg _{feed} /h)	73
5.2.	Effect of heating treatment (stabilization process) for wheat germ on machine capacity (kg _{feed} /h)	77
5.3.	Effect of atmospheric steaming process for wheat germ on oil recovery (%).....	77
5.4.	Effect of heating treatment (stabilization process) for wheat germ on oil recovery (%).....	82
5.5.	Effect of atmospheric steaming process for wheat germ on residual oil (%)	83
5.6.	Effect of heating treatment (stabilization process) for wheat germ on residual oil (%)	87
5.7.	Effect of atmospheric steaming process for wheat germ on oil productivity, (L/h).....	87
5.8.	Effect of heating treatment (stabilization process) for wheat germ on oil productivity, (L/h)	91
5.9.	Effect of atmospheric steaming process for wheat germ on	92

	specific energy consumption (SEC) (kWh/kg _{feed})	
5.10.	Effect of heating treatment (stabilization process) for wheat germ on specific energy consumption (SEC) (kWh/kg _{feed})	95
5.11.	Effect of atmospheric steaming process for wheat germ on barrel temperature, °C.....	96
5.12.	Effect of heating treatment (stabilization process) for wheat germ on barrel temperature, °C.....	100
5.13.	Oil extraction operation costs	103
5.14.	Economic feasibility of the developed expelling machine	103
6.	SUMMARY AND CONCLUSION	105
7.	REFERENCES	115
	ANNEX	
	ARABIC SUMMARY	

LIST OF TABLES

	Page
Table 2.1: Wheat germ proximate composition.....	4
Table 2.2: Physicochemical properties of wheat germ oil.....	10
Table 2.3: Comparison of fatty acid composition of WGO extracted with SC-CO ₂ and Soxhlet methods.....	11
Table 2.4: Effect of processing on the phosphorous content of WGO...	12
Table 3.1 Specification of suitable hopper dimensions of the expelling machine	42
Table 3.2: Specification of major component of the model screw press.	48
Table 4.1: Specifications of the developed an expelling machine	59
Table 5.1: Economic feasibility analysis for the developed expelling machine for a small scale mechanical oil extract for wheat germ.....	104

LIST OF FIGURES	Page
Fig. 2.1. Histological composition of wheat grain.	5
Fig. 2.2: Structure of an oil body.....	8
Fig. 2.3. Compression curve relating the volume of material displaced along the distance of the barrel cage during screw pressing	23
Fig. 2.4. Illustration of principle of single-feed double stage compression used in the developed screw	26
Fig. 3.1. The design flow chart for mechanical equipments.	38
Fig. 3.2. The main dimensions of screw shaft.	42
Fig. 3.3. Pitch and lead angle.	45
Fig. 3.4. Graph of height distribution through the screw shaft.	45
Fig. 3.5. Graph of assumed pressure distribution on the screw shaft from the inlet to outlet.	45
Fig. 3.6. Free body diagram of the screw shaft.	46
Fig. 4.1. Photograph of an expelling machine.	50
Fig. 4.2. Schematic digram of an expelling machine.....	51
Fig. 4.3. Design tree of the expelling machine	52
Fig. 4.4. Flat steel bars.	53
Fig. 4.5. Photograph of barrel rings with circular spacers.	54
Fig. 4.6. second barrel rings unit with circular spacers.	54
Fig. 4.7. The first screw.	55
Fig. 4.8. Photograph of second screw.	57
Fig. 4.9. The second screw.	57
Fig. 4.10. Conical choke mechanisms.	58
Fig. 4.11. Conical choke.	58
Fig. 4.12. Instruments for measuring angle of repose.	61
Fig. 4.13. A photographic of speedometer.	62
Fig.4.14. A photographic of clamp meter.....	62
Fig.4.15. A photographic of Infrared thermometer.	63
Fig.4.16. Sketch and photograph of the rotary heating stabilization unit	64

Fig. 4.17. Soxhlet unit used for extracting the residual oil.	69
Fig.5.1. Effect of screw speed and outlet clearance on machine capacity Kg/h at different moisture content levels.....	75
Fig.5.2. Effect of screw speed and outlet clearance on machine capacity Kg/h at different moisture content levels.	76
Fig.5.3. Effect of screw speed and outlet clearance on machine capacity Kgh^{-1} at stabilized wheat germ (9.5% moisture content).	79
Fig.5.4. Effect of screw speed and outlet clearance on oil recovery % at 13.2% moisture content.	79
Fig.5.5. Effect of screw speed and outlet clearance on oil recovery % at different moisture content levels. ...	80
Fig.5.6. Effect of screw speed and outlet clearance on oil recovery % at different moisture content levels...	81
Fig.5.7. Effect of screw speed and outlet clearance on residual oil,% at different moisture content levels.	85
Fig.5.8. Effect of screw speed and outlet clearance on residual oil (%) at different moisture content levels.....	86
Fig.5.9. Effect of screw speed and outlet clearance on residual oil (%) at stabilized wheat germ (9.5% moisture content)	89
Fig.5.10. Effect of screw speed and outlet clearance on oil productivity (L/h) at 13.2% moisture content.	89
Fig.5.11. Effect of screw speed and outlet clearance on oil productivity (L/h) at different moisture content levels.	90
Fig.5.12. Effect of screw speed and outlet clearance on oil productivity (L/h) at different moisture content levels.	93

Fig.5.13. Effect of screw speed and outlet clearance on specific energy consumption (kWh/kg _{feed}) at different moisture content levels.	94
Fig.5.14. Effect of screw speed and outlet clearance on specific energy consumption (kWh/kg _{feed}) at different moisture content levels.....	97
Fig.5.15. Effect of screw speed and outlet clearance on specific energy consumption (kWh/kg _{feed}) at stabilized wheat germ (9.5% moisture content) ...	98
Fig.5.16. Effect of screw speed and outlet clearance on barrel temperature (°C) at different moisture content levels.....	98
Fig.5.17. Effect of screw speed and outlet clearance on barrel temperature (°C) at different moisture content levels.....	101
Fig.5.18. Effect of screw speed and outlet clearance on barrel temperature (°C) at different moisture content levels.	102

LIST OF SYMBOLS

V	The flow rate of fluid, m ³ /sec.
R	Pore radius, m
ΔP	Pressure drop across a pore of length, Pa
L	Pore length, m
μ	Coefficient of viscosity, Pa.sec
L_p	Hydraulic conductivity of plasmodesmate, m ³ /sec. Pa
q	The flow rate of fluid
k	The coefficient of permeability
ρ	Fluid density
g	Gravitational acceleration
$\frac{\Delta u}{\Delta z}$	Hydraulic gradient in the fluid (pressure difference Δu over distance ΔZ).
σ_t	Total applied pressure,
σ_i	Kernel pressure; the pressure carried by the medium skeleton
U	Inter-kernel fluid pore pressure; the pressure carried by the medium fluid
Q_T	Theoretical volumetric flow rate of wheat germ, cm ³ /h.
\dot{m}	The maximum required mass flow rate
ρ_g	Wheat germ bulk density, g/cm ³
η_f	Feeding efficiency
η_v	Hopper volume efficiency
t_{int}	Time interval between filling and re-filling up the hopper
Q_{act}	Actual volumetric flow rate of wheat germ, cm ³ /h
V_H	The hopper actual volume, cm ³
D_h	Upper hole diameter of the hopper, cm.
h_h	Height of hopper, cm.
x	Sidelong length of the hopper, cm
θ	The inclination angle of hopper
ϕ	The repose angle.
P	Screw pitch
N	Number of turns of screw.
