Engineering Calculations of Single Screw Extruder and Milk Separator using Computer Aided Design System

Salha Elfatih Mohammed Ibrahim

B.Sc. (Honors) in Food Engineering Technology
University of Gezira (2014)

A Dissertation
Submitted to the University of Gezira in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Science

in

Food Engineering
Department of Food Engineering and Technology
Faculty of Engineering and Technology

May 2018
Engineering Calculations of Single Screw Extruder and Milk Separator using Computer Aided Design System

SalhaElfatih Mohammed Ibrahim

Supervision Committee:

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Magdi Ali Osman Mohammed</td>
<td>Main Supervisor</td>
<td></td>
</tr>
<tr>
<td>Dr. YousifElhadiElsideeg Ahmed</td>
<td>Co-supervisor</td>
<td></td>
</tr>
</tbody>
</table>

Date: May/2018
Engineering Calculations of Single Screw Extruder and Milk Separator using Computer Aided Design System

SalhaElfatih Mohammed Ibrahim

Examination Committee:

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Magdi Ali Osman Mohammed</td>
<td>Chair Person</td>
<td>................................</td>
</tr>
<tr>
<td>Dr. Hassan Ali Mudawi</td>
<td>External Examiner</td>
<td>................................</td>
</tr>
<tr>
<td>Dr. Ahmed Ibrahim Ahmed</td>
<td>Internal Examiner</td>
<td>................................</td>
</tr>
</tbody>
</table>

Date of Examination: 9/May/2018
بِلِّيَّة

يرفع الله الذين آمنوا منكم والذين أؤثروا العالم درجات والله ينتمحون خيرَ (صحب الله العلي الغالي)

المجلة 11
Dedications

I would like to dedicate this work to

My beloved Mother
My beloved Father
My brother and sisters
My teachers
And all my friends
Acknowledgments

In the Name of Allah, the Most Merciful, the Most Compassionate all praise be to Allah, the Lord of the worlds; and prayers and peace be upon Mohamed His servant and messenger.

First and foremost, I must acknowledge my limitless thanks to Allah, the Ever-Magnificent; the Ever-Thankful, for His help and bless.

I am totally sure that this work would have never become truth, without His guidance. I owe a deep debt of gratitude to our university for giving us an opportunity to complete this work.

I am grateful to some people, who worked hard with me from the beginning till the completion of the present research particularly my supervisor Dr. Magdi Ali Osman, who has been always generous during all phases of the research, and I highly appreciate the efforts expended by Dr. YousifElhadiElsideeg. I would like to take this opportunity to say warm thanks to all my beloved friend, who have been supportive along the way of doing my thesis. I also would like to express my wholehearted thanks to my family for their generous support they provided me throughout my entire life and particularly through the process of pursuing the master degree. Because of their unconditional love and prayers, I have the chance to complete this thesis.

I owe profound gratitude to my mother, Bahja, whose constant encouragement, limitless giving and great sacrifice, helped me accomplish my degree. I am very appreciative to my friends Dr. MaisaBushra Omer and Soufan Mohammed Misskien, who participated in this study.

Last but not least, deepest thanks go to all people who took part in making this thesis real.
Engineering Calculations of Single Screw Extruder and Milk Separator using Computer Aided Design System

SalhaElfatih Mohammed Ibrahim

Abstract
Computers have entered various fields of science, including food engineering, which deals with devices, equipment and food substances together in order to facilitate and accelerate the process of conducting engineering calculations both in the fields of equipment and production lines design, or in the field of food processing. This study aimed to use specific computer programs, to develop a software program to audit the complex design calculations of some food processing equipment, specifically single screw extruder and milk separator, for later use in unit operation laboratories, or in the food processing equipment manufacturing plants in general. The traditional manual calculation methods were used to obtain reliable results first, then MatLab and Visual Basic programs were used to generate these calculations. For this purpose, using engineering equations of these devices, the necessary algorithms were created and then the codes were written for each program. After that, interfaces were opened, and then they were supplied with all necessary components, to perform calculations as required. It was found that the required engineering computational results that help to design single screw extruder according to the input data were: the flow rate of the processed material in the extruder screw $1.153 \times 10^{-5} \text{ m}^3/\text{sec}$, the pressure necessary for the process flow $1.447 \times 10^9 \text{ Pa}$, and the productivity of the extruder $1.153 \times 10^{-5} \text{ m}^3/\text{sec}$. The results of engineering calculations required and help for the design of the milk separator according to the input data were: the separator productivity $1.7406 \times 10^3 \text{ l/h}$ and the motor power $0.0444 \text{ kwt}$. A comparison studies were carried out between the results obtained traditionally and those obtained using the MatLab and Visual Basic programs; also engineering calculations for other devices were performed with different data in the same manner. It was found that the accuracy and speedily results of these operations were confirmed. The study recommends that, this proposed program should be supported and developed by adding engineering calculations of other devices, in order to get an integrated programming package for engineering and design calculations of food processing equipment in a more comprehensive manner.
الحسابات الهندسية لجهاز الطهي مع البثق ذو اللولب الواحد وفراز الحليب

بتアクセヘデンスに使用するシステムの設計における支援

ملخص الدراسة

دخلت الحاسبات الآلية في مجالات العلوم المختلفة و من ضمنها هندسة الأغذية التي تتعامل مع الأجهزة والمعدات والمواد الغذائية معاً، وذلك لتسهيل وتسريع عمليات إجراء الحسابات الهندسية سواء في مجال تصميم المعدات وخطوطة الإنتاج أو في مجال التصنيع الغذائي. فهذة الدراسة إلى استخدام الحاسب الآلي وخصوصا البرامج الحاسبية المتاحة والمُستخدمة في مجالات العلوم المختلفة لتطوير برنامج بمساعدة الحاسوب وتسريع وتفحص عمليات الحسابات الهندسية والتصميمية المُعَدئة لبعض معدات التصنيع الغذائي وتحديد أداء جهاز الطهي مع البثق ذو اللولب الواحد وجهاز فراز الحليب، وذلك لاستخدامها لاحقاً في معامل ووحدات التشغيل أو في مصانع إنتاج معدات التصنيع الغذائي بصورة عامة. تم استخدام طريقة الحسابات اليدوية التقليدية للحصول على نتائج موثوقة أولاً ثم استخدام برامج المتلاب والفيجوال بيسك لحوسبة هذه العمليات. ولن هذا الغرض وباستخدام المعادلات الهندسية لهذه الأجهزة تم إنشاء الخوارزميات اللازمة ومن ثم كتابة الشفرات لكل برنامج، وبعد ذلك تم تصميم نواذ على واجهات البرامج وتم تنزيلها بكل المكونات اللازمة والتي يتمكنا من القيام بإجراء العمليات الحسابية بصورة موثوقة. وُجد أن النتائج الحسابية الهندسية المطلوبة والمُساعدة على تصميم جهاز الطهي مع البثق ذو اللولب الواحد على حسب المُعْطيات المدخلة هي: معدل سريان المادة المُعالجة في لولب الجهاز 1.153*10⁵ m³/sec 7.1447*10⁵Pa المضغط النازل لجريان العملية ونتاجية جهاز الطهي مع البثق 1.1531.153*10⁵ m³/sec 7.1447*10⁵l/h. كما أن النتائج الحسابية الهندسية المطلوبة والمُساعدة على تصميم جهاز فراز الحليب على حسب المُعْطيات المدخلة هي: إنتاجية الفراز 31.74060.00444 wkw وبين النتائج المحصلة عليها تقليدياً وذلك التي تم الحصول عليها بواسطة استخدام برامج المتلاب والفيجوال بيسك، كما تم إجراء حسابات هندسية لأجهزة أخرى بمعدات مختلفة بنفس الطرق، وقد تم التأكيد على صحة ودقة وسرعة العمليات الحاسبية المُنجزة. توصي الدراسة بتعميق وتطوير هذا البرنامج المقترح بحسابات هندسية لأجهزة أخرى حتى يتم الحصول على حزمة مُبرمجة متكاملة لإجراء العمليات الحسابية الهندسية والتصميمية لعدة التصنيع الغذائي بصورة أشمل.
# Table of Contents

<table>
<thead>
<tr>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>الادية</td>
<td>iv</td>
</tr>
<tr>
<td>Dedications</td>
<td>iv</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>vi</td>
</tr>
<tr>
<td>Abstract</td>
<td>vii</td>
</tr>
<tr>
<td>ملخص الدراسة</td>
<td>viii</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>ix</td>
</tr>
<tr>
<td>List of Tables</td>
<td>xiii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>xiv</td>
</tr>
<tr>
<td>Nomenclature</td>
<td>ix</td>
</tr>
</tbody>
</table>

**Chapter One: 1. Introduction**

1.1 General Introduction 1
1.2 Problem Identification and Justification 2
1.3 Objectives 3

**Chapter Two: 2. Literature Review**

2.1 Introduction 4
2.2 Extrusion 5
2.2.1 Types of Extruder 6
2.2.1.1 Single-Screw Extruder 6
2.2.1.2 Twin-Screw Extruder 6
2.2.2 Extruder Components 7
2.2.2.1 Screw 9
2.2.2.2 Barrel 11
2.2.2.3 Die 12
2.2.2.4 Feed System 13
2.2.2.5 Drive System 14
2.2.3 Extruder Variables 14
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2.3.1 Screw Speed</td>
<td>15</td>
</tr>
<tr>
<td>2.2.3.2 Barrel Temperature</td>
<td>15</td>
</tr>
<tr>
<td>2.2.3.3 Feed Rate</td>
<td>15</td>
</tr>
<tr>
<td>2.2.4 Feed Ingredient Variables</td>
<td>15</td>
</tr>
<tr>
<td>2.2.4.1 Feed Composition</td>
<td>15</td>
</tr>
<tr>
<td>2.2.4.2 Feed Moisture</td>
<td>16</td>
</tr>
<tr>
<td>2.2.4.3 Feed Particle Size</td>
<td>17</td>
</tr>
<tr>
<td>2.3 Milk Separation or Cream Separation</td>
<td>21</td>
</tr>
<tr>
<td>2.3.1 Centrifugation</td>
<td>21</td>
</tr>
<tr>
<td>2.3.1.1 Theory</td>
<td>21</td>
</tr>
<tr>
<td>2.3.1.2 Equipment</td>
<td>23</td>
</tr>
<tr>
<td>2.3.1.2.1 Tubular Bowl Centrifuge</td>
<td>23</td>
</tr>
<tr>
<td>2.3.1.2.2 Disc Bowl Centrifuge</td>
<td>24</td>
</tr>
<tr>
<td>2.3.2 Continuous centrifugal separation of milk</td>
<td>27</td>
</tr>
<tr>
<td>2.3.3 Warm Milk Skimming</td>
<td>31</td>
</tr>
<tr>
<td>2.3.4 Cold Milk Skimming</td>
<td>31</td>
</tr>
<tr>
<td>2.3.5 Structure and principle of operation</td>
<td>33</td>
</tr>
<tr>
<td>2.4 Computer Aided Design (CAD)</td>
<td>34</td>
</tr>
<tr>
<td>2.4.1 MATLAB</td>
<td>35</td>
</tr>
<tr>
<td>2.4.2 Microsoft Visual Basic</td>
<td>36</td>
</tr>
<tr>
<td>2.4.3 Programs and Programming Languages</td>
<td>37</td>
</tr>
<tr>
<td>2.4.4 Procedural and Object-Oriented Programming</td>
<td>38</td>
</tr>
<tr>
<td>2.4.5 More About Controls and Programming</td>
<td>39</td>
</tr>
<tr>
<td>2.4.6 Types of Programming Language</td>
<td>40</td>
</tr>
<tr>
<td>2.4.6.1 Machine Language</td>
<td>41</td>
</tr>
<tr>
<td>2.4.6.2 Assembly Language</td>
<td>41</td>
</tr>
<tr>
<td>2.4.6.3 High Level Language</td>
<td>41</td>
</tr>
<tr>
<td>2.4.7 Basic</td>
<td>42</td>
</tr>
<tr>
<td>2.4.8 Choosing a Programming Language</td>
<td>44</td>
</tr>
<tr>
<td>2.4.9 The Visual Basic Programming Language</td>
<td>44</td>
</tr>
<tr>
<td>2.4.9.1 Three Types of Visual Basic Programs</td>
<td>45</td>
</tr>
<tr>
<td>2.4.9.2 An Introduction to Object-Oriented Terminology</td>
<td>45</td>
</tr>
<tr>
<td>Chapter Three: 3. Materials and Methods</td>
<td>47</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>3.1 Materials</td>
<td>48</td>
</tr>
<tr>
<td>3.2 Methods</td>
<td>50</td>
</tr>
<tr>
<td>3.2.1 Method of design calculation of single screw extruder</td>
<td>50</td>
</tr>
<tr>
<td>3.2.1.2 The flowchart (Algorithm) of single screw extruder design calculation</td>
<td>52</td>
</tr>
<tr>
<td>3.2.2 Method of design calculation of milk separator</td>
<td>53</td>
</tr>
<tr>
<td>3.2.2.2 The flowchart (Algorithm) of milk separator design calculations</td>
<td>55</td>
</tr>
<tr>
<td>3.3 Matlab Programming</td>
<td>56</td>
</tr>
<tr>
<td>3.3.1 The Command Window</td>
<td>56</td>
</tr>
<tr>
<td>3.3.2 The M-File</td>
<td>57</td>
</tr>
<tr>
<td>3.3.3 Arithmetic Operators</td>
<td>59</td>
</tr>
<tr>
<td>3.4 Visual Basic Programming</td>
<td>61</td>
</tr>
<tr>
<td>3.4.1 Graphical User Interface Programs</td>
<td>61</td>
</tr>
<tr>
<td>3.4.2 Create Visual Studio IDE</td>
<td>61</td>
</tr>
<tr>
<td>3.4.3 The Designer Window</td>
<td>63</td>
</tr>
<tr>
<td>3.4.4 Design-Time and Run-Time Operating Modes</td>
<td>64</td>
</tr>
<tr>
<td>3.4.5 Creating a Visual Basic IDE Program</td>
<td>65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter Four: 4. Results and Discussion</th>
<th>66</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 An Overview</td>
<td>66</td>
</tr>
<tr>
<td>4.1.1 Manual design calculations results for extruder</td>
<td>66</td>
</tr>
<tr>
<td>4.1.2 The results of extruder design calculations using MatLab</td>
<td>68</td>
</tr>
<tr>
<td>4.1.3 The results of extruder design calculations using Visual Basic</td>
<td>70</td>
</tr>
<tr>
<td>4.2.1 Manual design calculations of milk separator</td>
<td>73</td>
</tr>
<tr>
<td>4.2.2 Design calculations results of milk separator using Matlab</td>
<td>75</td>
</tr>
<tr>
<td>4.2.3 Design calculations results of milk separator using Visual Basic</td>
<td>77</td>
</tr>
<tr>
<td>4.3 Evaluation of programing results of design calculations of single screw extruder and milk separator</td>
<td>78</td>
</tr>
<tr>
<td>4.4 Discussion</td>
<td>80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter Five: 5. Conclusions And Recommendations</th>
<th>81</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 Conclusions</td>
<td>81</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>5.2 Recommendations</td>
<td>81</td>
</tr>
<tr>
<td>References</td>
<td>82</td>
</tr>
<tr>
<td>Appendices</td>
<td>86</td>
</tr>
</tbody>
</table>
# List of Tables

<table>
<thead>
<tr>
<th>Table No.</th>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2-1)</td>
<td>Effect of primary extrusion variables on secondary extrusion variables.</td>
<td>19</td>
</tr>
<tr>
<td>(2-2)</td>
<td>Operating data for different types of extruder</td>
<td>20</td>
</tr>
<tr>
<td>(2-3)</td>
<td>Popular programming languages</td>
<td>38</td>
</tr>
<tr>
<td>(2-4)</td>
<td>Visual Basic controls</td>
<td>40</td>
</tr>
<tr>
<td>(2-5)</td>
<td>Comparison between type of languages</td>
<td>42</td>
</tr>
<tr>
<td>(3-1)</td>
<td>Basic values of the various parameters for Extruder design calculation</td>
<td>48</td>
</tr>
<tr>
<td>(3-2)</td>
<td>Basic values of the various parameters for Milk separator design calculation</td>
<td>49</td>
</tr>
<tr>
<td>(3-3)</td>
<td>Arithmetic operations between two scalars</td>
<td>59</td>
</tr>
<tr>
<td>(3-4)</td>
<td>Mathematical functions</td>
<td>60</td>
</tr>
<tr>
<td>(4-1)</td>
<td>Comparison between three design calculations methods of single screw extruder</td>
<td>78</td>
</tr>
<tr>
<td>(4-2)</td>
<td>Results of computer programs evaluation of design calculations of single screw extruder</td>
<td>79</td>
</tr>
<tr>
<td>(4-3)</td>
<td>Comparison of the results between two different milk separators design calculations</td>
<td>79</td>
</tr>
</tbody>
</table>
# List of Figures

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Title</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2.1)</td>
<td>Depict key components of single - screw and twin - screw extruders</td>
<td>7</td>
</tr>
<tr>
<td>(2.2)</td>
<td>Photograph of single screw extruder</td>
<td>8</td>
</tr>
<tr>
<td>(2.3)</td>
<td>Sections within the barrel of a single screw extruder</td>
<td>8</td>
</tr>
<tr>
<td>(2.4)</td>
<td>Schematic drawing of screw parameters</td>
<td>9</td>
</tr>
<tr>
<td>(2.5)</td>
<td>Food extrusion die</td>
<td>13</td>
</tr>
<tr>
<td>(2.6)</td>
<td>Interrelationships among extruder and ingredient variables</td>
<td>18</td>
</tr>
<tr>
<td>(2.7)</td>
<td>Major applications of the centrifuges</td>
<td>23</td>
</tr>
<tr>
<td>(2.8)</td>
<td>A tubular bowl centrifuge</td>
<td>24</td>
</tr>
<tr>
<td>(2.9)</td>
<td>Working principle of a tubular bowl centrifuge</td>
<td>24</td>
</tr>
<tr>
<td>(2.10)</td>
<td>Diagrams of centrifugal separators</td>
<td>25</td>
</tr>
<tr>
<td>(2.11)</td>
<td>A disc bowl centrifuge</td>
<td>26</td>
</tr>
<tr>
<td>(2.12)</td>
<td>Working principle of a disc bowl centrifuge</td>
<td>26</td>
</tr>
<tr>
<td>(2.13)</td>
<td>The basic principle of a so-called semi open milk separator</td>
<td>26</td>
</tr>
<tr>
<td>(2.14)</td>
<td>Domestic cream separator</td>
<td>27</td>
</tr>
<tr>
<td>(2.15)</td>
<td>A centrifuge clarifier bowl</td>
<td>28</td>
</tr>
<tr>
<td>(2.16)</td>
<td>A centrifuge separator bowl</td>
<td>29</td>
</tr>
<tr>
<td>(2.17)</td>
<td>(a) Sectional view of part of the disc stack, (b) Disc stack with distribution holes and caulks</td>
<td>29</td>
</tr>
<tr>
<td>(2.18)</td>
<td>Separator bowl components</td>
<td>32</td>
</tr>
<tr>
<td>(3.1)</td>
<td>The research methodology flow chart</td>
<td>47</td>
</tr>
<tr>
<td>(3.2)</td>
<td>Flowchart of single screw extruder design calculations</td>
<td>52</td>
</tr>
<tr>
<td>(3.3)</td>
<td>Flowchart of milk separator design calculations</td>
<td>55</td>
</tr>
<tr>
<td>(3.4)</td>
<td>The MATLAB command interface</td>
<td>57</td>
</tr>
<tr>
<td>(3.5)</td>
<td>The MATLAB command Window</td>
<td>57</td>
</tr>
<tr>
<td>(3.6)</td>
<td>How to open m-file editor window</td>
<td>58</td>
</tr>
<tr>
<td>(3.7)</td>
<td>The m-file editor window</td>
<td>59</td>
</tr>
<tr>
<td>(3.8)</td>
<td>Visual Studio Start Page</td>
<td>62</td>
</tr>
<tr>
<td>(3.9)</td>
<td>Visual Studio Designer window</td>
<td>63</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>(3.10)</td>
<td>Visual Studio Code window</td>
<td>64</td>
</tr>
<tr>
<td>(3.11)</td>
<td>Program form and controls</td>
<td>65</td>
</tr>
<tr>
<td>(4.1)</td>
<td>(a, b) The code of extruder design calculation in m-file</td>
<td>68</td>
</tr>
<tr>
<td>(4.2)</td>
<td>(a, b) The result of extruder design calculation in command window</td>
<td>69</td>
</tr>
<tr>
<td>(4.3)</td>
<td>Extruder design calculations form</td>
<td>70</td>
</tr>
<tr>
<td>(4.4)</td>
<td>The results of extruder design calculations form when selecting a ring shape orifice (Ring's hole)</td>
<td>71</td>
</tr>
<tr>
<td>(4.5)</td>
<td>The result of extruder design calculation form when selecting a conic shape orifice (Cone hole)</td>
<td>72</td>
</tr>
<tr>
<td>(4.6)</td>
<td>(a, b) The code of milk separator design calculations in m-file</td>
<td>75</td>
</tr>
<tr>
<td>(4.7)</td>
<td>(a, b) The results of milk separator design calculation in command window</td>
<td>76</td>
</tr>
<tr>
<td>(4.8)</td>
<td>Milk separator design calculation form</td>
<td>77</td>
</tr>
<tr>
<td>(4.9)</td>
<td>Design calculations results of milk separator form</td>
<td>77</td>
</tr>
</tbody>
</table>
(CAPD) Computer-Aided Process Design

(HTST) High-Temperature Short-Time

(L/D) Length to Diameter Ratio

(CAD) Computer-Aided Design

(EDA) Electronic Design Automation

(MDA) Mechanical Design Automation

(CAD) Computer-Aided Drafting

(2D) Two-Dimensional

(3D) Three-Dimensional

(IT) Information Technology

(H/W) Hardware

(S/W) Specialized Software

(PDM) Product Data Management

(GUI) Graphical User Interface

(LINPACK) LINear system PACKage

(EISPACK) ElgenSystem PACKage

(OS) Operating System

(OOP) Object-Oriented Programming

(IDE) Integrated Development Environment

(Ring’s hole) Ring shape orifice

(Cone hole) Cone shape orifice
Chapter One

1. Introduction

1.1 General Introduction

Food Engineering applications and development have been transformed by revolutionary advances in computer technology, molecular biology, and materials science in the past two decades. Computers are increasingly being used for development of materials science as well as for analysis, simulation and control of food processes. Computer applications in Food Engineering will continue to grow rapidly, with progress in sensor technology and artificial intelligence. This will enable progress in fields that are limited by the shortage of reliable on-line measurements of product quality. Several critical obstacles must be overcome by these new technologies; the scientific impediments consist of a lack in knowledge of relations between physicochemical and sensory properties, complexity of food components and their chemical reactions, and intricacy in on-line measurement of product properties. There is a need to link food science research with food engineering and process technologies in such a way as to facilitate an increase in product development efficiency and an improvement in product quality and value. One way would be to research the area of computer-aided process design (CAPD) (Bon, 2010).

Food engineering is the multidisciplinary field of applied physical sciences combined with the knowledge of product properties. Food engineers provide the technological knowledge transfer essential to the cost-effective production and commercialization of food products and services. In particular, food engineers develop and design processes and equipment in order to convert raw agricultural materials and ingredients into safe, convenient, and nutritious consumer food products. However, food engineering topics are continuously undergoing changes to meet diverse consumer demands, and the subject is being rapidly developed to reflect market needs (Erdogdu, 2006).

Although not specific for Food Engineering, there are many general purposes, software packages that could be useful for Food Engineers. The software found in the market deals with oriented languages directed towards solving general mathematical problems or data treatment: of course, the user should program its particular application. Among the general-purpose software types, Matlab and
VISUAL BASIC are gaining a reputation for adeptness and have already appeared in Food Engineering books.

MATLAB and VISUAL BASIC companion toolboxes provide engineers, scientists, mathematicians, and students of these fields with an environment for technical computing applications. They are much more than a programming language like C, C++ or FORTRAN. Technical computing includes mathematical computation, analysis, visualization, and algorithm development. The flexible MATLAB and VISUAL BASIC environment lets the user perform advanced analyses, visualize data, and develop algorithms by applying the wealth of functionality available. With their more than 1000 mathematical, statistical, scientific and engineering functions, MATLAB and VISUAL BASIC give you immediate access to high performance numerical computing (Hahn and Valentine, 2007).

In this study MATLAB and VISUAL BASIC programs were used as tools for solving complex engineering and design problems in food engineering field, specifically for design calculations of some food processing equipment (Single Screw Extruder and Milk Separator).

1.2 Problem identification and Justification

Nowadays, a great deal of more or less general-purpose software exists that could be useful in Food Engineering. The main drawback in most cases being the design calculations of food processing equipment. Currently, industry standard flow sheeting and design programs are widely used by chemical engineers. However, existing programs for food processing applications are limited in their ability to handle the wide variety of processes, equipment and products encountered in the food industry. A program designed specifically for the food industry would diminish turn-around time in preliminary design and analysis of processes. Due to food complexity and the heterogeneity of the attributes (microbiological, chemical, biochemical, sensorial), the results are still scarce, despite the efforts undertaken.
1.3 Objectives

The main objective of this study is to:

- Supply Food Engineering Laboratories in the Department of Food Engineering and Technology, University of Gezira with computer applications that lead to accuracy in laboratories calculations results, ease of use and save time and effort.

Specific objective:

The specific objectives of this study are to:

- Study and investigate the commercial software that help to understand and prepare programming software applications for Food Engineering Laboratories.
- Develop a programming software package for solving engineering and design problems and calculations of some food processing equipment.
2. Literature Review

2.1 Introduction:

Design and calculation of components of the machinery is a creative activity using theoretical and practical experience. This activity must be geared mainly to meet the requirements. At present, virtually all areas of design activities supported by computer technology that can be effectively used in the design of machinery components particularly in the construction of technical documentation and field strength calculations (Kulik and Pasko, 2012). The engineer should know how to work with commercial software because it is universally used, performs well and has a forthcoming interface making it user friendly. However, the engineer must also know how to develop software to solve specific problems, because many of the calculations found in one’s professional career will be unique.

In the development of food engineering, one of the many challenges is to employ modern tools and knowledge, such as computational materials science and nanotechnology, to develop new products and processes. Simultaneously, improving food quality, safety, and security remain critical issues in food engineering study. New packaging materials and techniques are being developed to provide more protection to foods, and novel preservation technologies are emerging to enhance food security and defense. Additionally, process control and automation regularly appear among the top priorities identified in food engineering. Advanced monitoring and control systems are developed to facilitate automation and flexible food manufacturing (Erdogdu, 2006).

Food Engineering is the application of engineering, science and technology to the processing, manufacture, production, new product development, evaluation, distribution and packaging of food products. It integrates and applies knowledge within the disciplines of chemistry, engineering, biology, and nutrition to preserve, process, package, and distribute foods that are nutritious, wholesome, affordable, desirable, and safe to eat.

Food Engineering students have training in basic sciences such as mathematics, physics, organic chemistry, inorganic chemistry, analytical chemistry, biochemistry,
microbiology, etc. They also study the computer science in food engineering, the chemical composition of food and food ingredients; their physical, biological and biochemical properties; the microbiology of foods; and the interaction of food constituents with each other and their environment (Önal and Ötles, 2007).

Software has a critical role in all aspects of the development cycle from discovery to diffusion. Basic studies are affected by software, as literature searches, database inquiries, and inter-student exchanges are usually performed through software. Software, therefore, determines the data students get and the questions they ask. Product developments and designs are greatly influenced by software such as CAD/CAM, and software can play an especially important role when physical experiments for food engineering students are dangerous or impossible (Önal and Ötles, 2007).

2.2 Extrusion:

Is a thermomechanical process where shaping of a plastic or dough-like material is obtained by forcing it through a die or restriction. Extruders are high-temperature short-time (HTST) reactors that can transform a variety of raw materials into modified intermediate and finished products. Extrusion has an unlimited range of applications and continuous production capabilities to meet new market challenges, which make them attractive to processors and markets (Rosato, 1998). Riaz (2000) lists numerous functions of extrusion, such as agglomeration, degassing, dehydration, expansion, gelatinization, grinding, homogenization, mixing, pasteurization and sterilization, protein denaturation, texture alteration, thermal cooking, shearing, shaping, and unitizing. Advantages of the extrusion process are versatility/adaptability, energy efficiency, low cost, no effluent, process scale-up, continuous high-throughput processing, ability to handle ingredients with a range of moisture contents from relatively dry to very wet materials, high product quality (improved textural and flavor characteristics), and control of the thermal changes which occur in the material.

Extrusion is finding ever-increasing application in the food industry, such as the production of ready-to-eat cereals, pasta, snacks, pet food, fish foods, and confectionary products, apart from its obvious applications in the plastics industry. The production of multidimensional third-generation snacks using extrusion are efficient, economical to run and result in a product with built-in marketing
flexibility due to long shelf-life and high bulk density prior to frying or puffing (Huber, 2001).

2.2.1 Types of Extruder:

According to Frame (1994), hydraulic ram, roller, and screw-type extruders are the three types of extruder found in the food industry. However, Riaz (2000) advocated that in today’s food industry the term “extruder” typically means a machine with Archimedean screw characteristics (a rotating flight screw which fits sufficiently tightly in a cylinder to convey a fluid) that continuously processes a product. Recently, Clark (2010) observed that roll extruders are commonly used in making confections and snacks by forming strips or ribbons of plastic material such as sugar-based taffy or cereal-based dough. The special features of the screw extruder are continuous processing and mixing ability, properties very different from the other two types of extruder. Single- and twin-screw extruders are the most widely used in the food and feed industry (Senanayake and Clarke, 1999).

2.2.1.1 Single-screw Extruder:

Single-screw extruders are readily available in a number of shapes and sizes, and the barrel, screw configuration, and screw can be varied to suit a particular variety of product characteristics (Harper, 1978). The main advantages of single-screw over twin-screw extruders are that they are mechanically very simple and the cost is half the price of similar-sized twin-screw extruders (Riaz, 2000). Because of this, single-screw extruders are used wherever possible in the industry and in academic research. The material is conveyed along the length of the screw by a drag flow mechanism, where drag is directly proportional to screw speed. In general, single-screw extruders possess poor mixing ability, which necessitates premixing of ingredient prior to extrusion.

2.2.1.2 Twin-screw Extruder:

This comprises two screws rotating either in the same direction (co-rotating) or in the opposite direction (counter-rotating). Based on screw configuration and degree of intermeshing, twin-screw extruders can be classified into fully intermeshing, partially intermeshing, and non-intermeshing. Co-rotating twin-screw extruders are the most common in the food and snack industry for their pumping efficiency, good control over residence time distribution, self-cleaning mechanism, and uniformity of processing (Schuler, 1986). Counter-rotating intermeshing twin-screw extruders were developed for the processing of polyvinyl
chloride, which comprises resin beads that are slippery and difficult to process in a single-screw extruder (Clark, 2010). Twin-screw extruders are more flexible in operation than single-screw extruders but they are more expensive. Some of the advantages of twin-screw extruders include ability to handle a variety of materials (viscous, oily, sticky, and wet) and a wide range of particle sizes, nonpulsating feed, positive pumping action, self-cleaning, and scaling-up (Riaz, 2000).

2.2.2 Extruder Components:

Screw, barrel, die, feed and drive systems are the major components of an extruder and their details are discussed in this section. Figures 2.1 depict key components of single-screw and twin-screw extruders. The food contact surface should be noncorrosive and nontoxic. All screws and liners are constructed of high-quality, wear-resistant, stainless steel alloys (heat treatable 400 series).

Figure 2.1 (a) A screw element; (b) typical screw elements; (c) screw is formed by attaching several elements together in various configurations; (d) assembled twin-screw extruder during operation (Ahmed and Rahman, 2012)
Figure 2.2 Photograph of single-screw extruder
(Courtesy of Leistritz Company)

Figure 2.3 Sections within the barrel of a single screw extruder.
(Harper, 1989)
2.2.2.1 Screw:

The screw is the central part of an extruder. Important screw parameters are given in Figure 2.4.

![Schematic drawing of screw parameters](Ahmed and Rahman, 2012)

- **Screw diameter (D)** is the distance between two flights across the screw shaft.
- **Channel depth (h)** is the distance from the top of the flight to the root.
- **Pitch (t)** is the distance between consecutive flights. All these parameters vary depending on design and the manufacturer.
- **Helix angle (Φ)** is the angle between the flight and a line perpendicular to the screw shaft and it varies between 12 and 15°.
- **Clearance between flight tips and barrel (δ)** is usually 0.5 mm and will ensure efficient pumping of the material.
- **Axial flight width (e)** of a screw is usually 10% of screw diameter.

The relative motion of the screw and barrel causes drag flow, which can be calculated by applying downstream velocity over the screw channel cross-section.

All extrusion processes experience heat generation from shearing of the viscous product. The drive motor power reflects the amount of heat generated during extrusion.

Some manufacturers make a screw in one piece (Figures 2.2), whereas others make them in segments (Figure 2.1 a). These segments are interchangeable in any order depending on the requirement on the continuous spline or key of the shaft. The most frequently employed screw configurations in the food industry are variable pitch, constant depth, increasing root diameter, increasing number of flights, and decreasing diameter. In single-screw extruders, screw geometry not only influences different
functions such as mixing, kneading, heat and pressure development but also the capacity of the extruder.

The movement and transformation of material within a single-screw extruder can be categorized into three sections: feeding, transition, and metering (Harper, 1981; Mercier et al., 1989). The feed throat of the screw accepts the low-density preconditioned or dry blend, with deep flights and long pitch facilitating movement. The function of the feed section is to ensure transportation of material down the screw and fill it completely. According to Harper (1981), the feed section is typically 10 – 25% of the total length of the screw. The transition section is also called the compression or kneading section because of its function. The food material loses its powder/granular form and changes into amorphous or plasticized dough, thereby increasing the density. Decrease in screw pitch and flight depth and angle are the most common ways to achieve transition/compression/kneading. The transition section is the longest section of the screw, being approximately half total screw length. This section of the screw can have forward, neutral, or reverse pitched elements depending on the application (Huber, 2000). The metering section is the part of the screw with shallow flights, which increases shear rate to maximum within the screw. A twin-screw extruder has more options because the entire screw section can consist of combinations of conveying elements, kneading elements, reverse screw elements, and additional elements. A combination of thermal and mechanical energy inputs plasticizes the food material above its melt transition temperature thus increasing the density. Compression ratio (channel depth at feed to channel depth at discharge) has a direct impact on shear development and temperature profile within the extruder barrel. A gradual decrease in flight depth in the direction of discharge and a decrease in pitch in the compression section are the most common ways to achieve compression (Harper, 1981). Compression ratio typically ranges from 1:1 to 5:1. However, for excluding air from cereal product and improving heat transfer efficiency, a modest compression of less than 3:1 is often used (Miller and Mulvaney, 2000).

A good mixing action is one of the most important functions of an extruder. As mentioned earlier, single-screw extruders have poor mixing ability, but this can be solved by introducing a mixing section in the screw configuration. A venting screw is used whenever necessary to vent moisture or other volatile gases trapped or contained within the extruder. A hole made in the barrel at a proper position and a
larger fill in the screw releases the pressure of the material. Moisture removal from the material reduces product expansion, which is desirable in nonexpanded product and for adjusting the density of aqua - feeds (Fang et al., 2003a).

2.2.2.2 Barrel:
The barrel is the cylindrical housing that accommodates the rotating screw(s) and should be mechanically strong enough to withstand the pressure developed in the barrel and resist wear (Senanayake and Clarke, 1999). A common practice is to relate the barrel length to diameter (L/D) ratio (Rosato et al., 2003) with throughput of a single - screw extruder (Giles et al., 2005). Barrels are composed of honed and nitrided stainless steel (416) in various L/D ratios. Nitriding may not be effective when abrasive materials are fed into the extruder. Hardening of stainless steel lowers corrosion resistance but has a negative effect on heat transfer. A thicker biometallc coating not only addresses abrasion and corrosion but also improves wear resistance (Giles et al., 2005). The L/D ratio can be varied to accommodate the geometrical design of the individual components. Harper (1981) notes that food extruders typically have L/D ratios ranging from 1: 1 to 20:1. For macaroni extrusion, screws are designed with L/D ratios between 6: 1 and 9: 1 with a screw diameter of 120-200 mm. However, an L/D ratio of 30 is required for accomplishing both cooking and forming of cereals in a single extruder (Miller and Mulvaney, 2000). Typically, twin - screw extruders have a shorter barrel length than that of single - screw extruders (Martelli, 1983). Martelli (1983) observed that the L/D ratio has no real meaning with twin - screw extruders in the usual sense, probably because the feeding is controlled by other devices as described later. Most of the food materials are sticky in nature during cooking and thus smooth - bore extruder barrels are not desirable. In order to accomplish positive transport, a material must slip on the rotating screw and this is enhanced if the barrel wall is grooved (longitudinal or spiral). In general, the extruder barrel is segmented and these segments are jacketed to allow temperature control of individual zones. Heating is typically accomplished with overheated steam, hot oil or band heaters, whereas cooling is achieved with tap water (Fang et al., 2003a). Heaters are usually located along the barrel, with a thermocouple in each zone to control the heaters and barrel temperature. Giles et al. (2005) noted that the most common type of thermocouple used on extruders is the K thermocouple. Miller and Mulvaney (2000) remarked that cooling facilitates the handling of products after extrusion by increasing the viscosity, which results in better retention of shape, and
by reducing stickiness. Low shear stress (forming) extruders are used to densify materials with high moisture content and have a long L/D ratio, which imparts a low level of mechanical energy per unit of throughput. Expanded products are produced in high shear stress extruders, which have the shortest L/D ratios.

2.2.2.3 Die

Dies are small openings at the end of the die section through which the product is extruded. These play an important role in deciding product physical properties such as density, expansion, surface texture, and final shape (Senanayake and Clarke, 1999) based on die design, extrusion configuration, processing conditions, and blend (Riaz, 2000). According to Huber (2000), highly restrictive dies increase barrel fill, residence time, and energy input. Chevananet al. (2007) studied the effect of die dimensions (Figure 2.5) on extrusion processing parameters and the properties of DDGS (dried distillers grains with solubles) - based extrudates. The simplest form of die is a hole, annular openings and slits being common. In general, small - scale extruders have only one opening in the die assembly, whereas large - scale extruders have multiple openings (Fang et al, 2003a), which alter die shear rates (Huber, 2000). Cereal processing normally requires multiple die openings (Miller and Mulvaney, 2000). High shear rate dies are responsible for imparting energy to starch - bearing products, thereby promoting starch damage that results in increase in water solubility in addition to other final product characteristics (Huber, 2000). Die insert, die plate, and breaker plates are other options of die used in the food industry.
2.2.2.4 Feed System:

In order to achieve consistent and uniform operation of an extruder, ingredient feeding should also be uniform and consistent. Feed throat and hopper geometry should allow material to flow freely into the extruder with minimum restriction. The feed hopper should have sufficient capacity for continuous operation and is an integral part of the feeding system. The feed rate of modern extruders is typically controlled by a variable speed auger, vibratory feeder weigh belts. Live bottoms are hoppers equipped with devices at their discharge outlets that ensure a continuous flow of ingredients; the volume of material must be sufficient to allow an orderly shutdown of the system if necessary. Rokey (2000) notes that when the fat content of a formulation exceeds 12%, that portion of fat above the 12% level should be introduced into a single-screw extruder in a separate ingredient stream. Preconditioning is an essential step, blending steam and water with dry ingredients to achieve temperature and moisture equilibrium. This operation not only hydrates the dry ingredient but also begins the cooking under slower shear conditions than those that exist in the extruder and this process allows the extruder to focus on final heating and forming (Clark, 2010). According to Mercier et al. (1989), preconditioning
increases residence time and capacity and reduces mechanical energy consumption. Preconditioning enhances flavor development and also aids final product texture, especially corn- and oat-based products (Huber, 2000). Modern preconditioners (arrowed in Figure 2.1 d) have a double-shaft design with different dimensions and speeds and can be operated at both atmospheric pressure and elevated pressures, resulting in better mixing with retention times between 2 and 4 min (Hauck, 1988).

2.2.2.5 Drive System:

The main function of the drive system is to provide power to rotate the extruder screw(s) (Fang et al., 2003a). The drive usually consists of an electric motor, a reduction gear, a torque transfer system, and a bearing support mechanism as mentioned by Rokey (2000). The size of the motor depends on the application and capacity of the extruder and may be as large as 400 hp (Harper, 1981). For instance, a low shear stress (slow speed) extruder may require a motor of 13 hp, whereas a high shear stress extruder used for the production of light density expanded snacks may require a motor of 160 hp per ton of throughput (Rokey, 2000). In general, synchronous speed of an electric motor is 1800 rpm; however, the actual maximum speed of the motor is 1725 – 1750 rpm because of slip (Harris, 2004). Harper (1981) notes that the screw speed of food extruders is normally less than 500 rpm. Required speed reduction is usually accomplished through a V belt or gear. Gearbox construction for a single-screw extruder is simple because the gearbox has only one output shaft to drive the screw. Gearbox construction for a twin-screw extruder is complicated because there are two output shafts to rotate two screws and also because there is limited radial space to accommodate bearings to support both the radial and thrust load from the extruder. In general, a three-bearing arrangement (two to support the radial load and a third to absorb thrust load) is used if a single-screw extruder has a motor size of more than 100 hp.

2.2.3 Extruder Variables:

Screw speed, barrel temperature, screw and barrel configuration, die opening, and feed rate are some of the parameters that affect extruder performance. Extruder operation depends on pressure build-up in the barrel (prior to exiting the die), slip at the barrel wall (transportation), and the degree of filling.
2.2.3.1 Screw Speed:

In general, screw speed is responsible for the rate of shear development and the mean residence time of the feed. The heat dissipation from the mechanical energy input to dough depends on screw speed, which in turn influences dough viscosity. As noted by Fang et al. (2003b), in some cases completion of texture formation and chemical reactions within the barrel require a long residence time, which corresponds to slow screw speed.

2.2.3.2 Barrel Temperature:

In order to avoid plugging and back-flow of material, the feed zone temperature is low and barrel temperature ramps up as the material travels down the screw. Barrel temperature usually has a positive effect on the degree of starch gelatinization and extrudate expansion, whereas it has a negative effect on product color especially at elevated temperatures. Several studies have indicated that elevated temperature leads to more moisture evaporation when exiting the die, and thus results in more expanded products (Chen et al., 1979; Kokini et al., 1992; Mercier et al., 1989).

2.2.3.3 Feed Rate

Extruder feed rate depends on the type of screw element, screw speed, type of feeding element, and feed moisture. According to Fang et al. (2003b), feed rate has an influence on residence time, torque requirement, barrel pressure, and dough temperature.

2.2.4 Feed Ingredient Variables:

Feed composition, moisture content, and particle size have the greatest effects on extrusion as discussed in this section.

2.2.4.1 Feed Composition:

The typical composition of any blend consists of starch, protein, lipid/fat, and fiber, which all contribute to product quality. Starch degradation usually reduces product expansion. It is essential that infant and weaning foods have high starch digestibility, which is largely dependent on full gelatinization (Camire, 2000). Lipid levels over 5–6% act as a lubricant, reducing slip within the barrel and resulting in poor product expansion. If the production of porous and expanded product is not the target, then a fat level of 15 – 18% can be used in single - screw extruders and a fat level of 20 – 22% in twin - screw extruders (Riaz, 2000). According to Camire, (2000), the lipid content of the extruded product is low. Rancidity is an issue for extruded products...
during storage because of lipid oxidation, which causes rapid deterioration of sensory and nutritional qualities. As Riaz, (2000) notes, sugar and salt (functional ingredients) will have more effects on wear than other ingredients. In cereal processing, sugar concentration has a negative effect on viscosity and high sugar concentration inhibits gelatinization, requiring higher temperatures to achieve the same degree of product expansion. Salt will assist in obtaining uniform moisture migration after drying of third-generation pellets during moisture equilibration. In general, salt reduces water activity, which leads to poor product expansion (Miller and Mulvaney, 2000). Generally, fiber is a noninteracting component that contributes to low expansion, cohesiveness, durability, and water stability. High fiber content usually results in high screw wear (Camire, 1998).

2.2.4.2 Feed Moisture:

Moisture is a critical variable that has multiple functions in starch gelatinization, protein denaturation, barrel lubrication, and final product quality (Fang et al., 2003b). According to Huber (2000), processing is uneconomical at in-barrel moistures below 20% and results in undesirable nutritional quality. However, a dry extruder can process materials with 8 – 22% moisture with no additional drying of extrudates (Said, 2000). In general, a medium shear stress extruder can handle food with 16 – 30% in barrel moisture, whereas a low shear stress extruder can handle food with more than 30% in barrel moisture (pasta dough has 31%). An increase in moisture content will have a pronounced effect on the rheological properties of the melt in the barrel (Miller and Mulvaney, 2000). High-moisture feeds decrease the mechanical energy requirement and reduce the wear and thereby operating cost. However, most extruded snacks have a moisture content between 8 and 12% and require additional drying to impart the desired texture and mouth-feel (Rokey, 2000). Camire (1998) reported that high moisture reduces vitamin loss during extrusion due to limited thermal degradation.

2.2.4.3 Feed Particle Size:

Riaz (2000) reports a general rule of thumb that the extruder feed should not have particles larger than one-third the diameter of die holes. Particle size also plays an important role not only in moisture distribution, heat transfer, and viscosity but also in final product quality. Coarse ingredient particles have more effect on wear than fine particles. A product composed of fine particles will have good water stability, water absorption index, expansion, and floatability.
Interactions between Extruder and Ingredient Variables:
A better understanding of the interactions between the extruder and ingredients within the barrel facilitates the development of not only screw and barrel configurations for converting mechanical energy to heat through friction but also new products. A literature survey reveals that extrusion experiments typically examine two to three variables, but many factors are important as shown in Figure 2.6. The outer circle shows the primary extruder and ingredient variables and the inner circle the secondary variables. The combination of Figure 2.6 and Table 2-1 should enhance understanding of the influence of primary extrusion variables on secondary extrusion variables.

According to Caldwell et al. (2000), viscosity is a reflection of the molecular weight of functional polymers and its measurement correlates with the energy input to an extruder. Although viscosity and residence time are placed in the inner circle, they are affected by other variables in the same circle. In general, an extruder converts ingredients into dough. Gelatinization of starch causes a substantial uptake of moisture, resulting in an increase in dough viscosity. An increase in feed rate and screw speed and reduction in L/D ratio has a negative effect on product residence time, which in turn affects dough viscosity. As screw speed increases, dough viscosity decreases because dough exhibits non-Newtonian behavior. According to Camire (2000), high temperature and low moisture are responsible for the formation of Maillard compounds and heterocyclic chemicals, resulting in a typical cooked grain flavor. High barrel temperature, screw speed, specific mechanical energy (SME), low feed moisture, die diameter, and throughput are the variables that increase vitamin loss during extrusion (Killeit, 1994). A die with long land results in a dense product and thereby increased bulk density (Williams, 2000). The amount of starch, protein, and fat present in the blend affects product expansion and firmness (Riaz, 2000).

According to Fichtali and van de Voort (1989), the torque indicates the amount of energy absorbed by the material due to shear exerted by the screw(s). Motor torque is a very sensitive indicator of stable operation during extrusion. Fluctuation in motor torque usually indicates nonsteady-state extrusion conditions; it occurs when there is erratic feeding and surging, and may cause plugging of the die. Therefore, one must ensure uniform and consistent feeding. SME indicates the extent of molecular
break down or degradation that the material undergoes during the extrusion process. An increase in moisture content decreases the viscosity of dough in the extruder, shortens the mean residence time, and reduces the conversion ratio of extruder mechanical energy into heat energy, and consequently SME becomes lower.

![Figure 2.6 Interrelationships among extruder and ingredient variable (Ahmed and Rahman, 2012).](image)

Table 2-1 Effect of primary extrusion variables on secondary extrusion variables (Ahmed and Rahman, 2012).
Single-screw extruders can be classified according to the extent of shearing action on the food into:

<table>
<thead>
<tr>
<th>Blend</th>
<th>Extruder type and die details</th>
<th>Extrusion variable</th>
<th>Range</th>
<th>Torque</th>
<th>SME</th>
<th>Die pressure</th>
<th>Product temperature</th>
<th>Apparent viscosity</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cornmeal</td>
<td>Co-rotating twin-screw extruder L/D 15:1, 2 dies of 3.18 mm</td>
<td>Screw speed</td>
<td>200–400 rpm</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>NR</td>
<td>ONWULA et al. (1994)</td>
</tr>
<tr>
<td>Rice flour</td>
<td>Co-rotating twin-screw extruder L/D 30.8:1, no die</td>
<td>Temperature</td>
<td>80–120°C</td>
<td>-</td>
<td>-</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>GUHA et al. (1997)</td>
</tr>
<tr>
<td>Corn grits</td>
<td>Co-rotating twin-screw extruder, slit die</td>
<td>Temperature</td>
<td>90–160°C</td>
<td>-</td>
<td>-</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>LI et al. (2004)</td>
</tr>
<tr>
<td>DDGS-soy and corn flour</td>
<td>Single-screw extruder, L/D 20:1</td>
<td>Temperature</td>
<td>100–160°C</td>
<td>-</td>
<td>-</td>
<td>NS</td>
<td>-</td>
<td>-</td>
<td>CHEVANAN et al. (2007)</td>
</tr>
<tr>
<td>Fish-rice flour</td>
<td>Co-rotating twin-screw extruder L/D 25:1, die 3 mm</td>
<td>Temperature</td>
<td>125–145°C</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>NR</td>
<td>PANSAWAT et al. (2008)</td>
</tr>
<tr>
<td>Chickpea-potato flour</td>
<td>Co-rotating and intermeshing twin-screw extruder L/D 24:1, 2 dies of 2.5 mm</td>
<td>Temperature</td>
<td>150–170°C</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>NR</td>
<td>MENG et al. (2010)</td>
</tr>
<tr>
<td>DDGS-soy and corn flour</td>
<td>Single-screw extruder, L/D 20:1, die diameter</td>
<td>Temperature</td>
<td>100–160°C</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>NR</td>
<td>CHEVANAN et al. (2010)</td>
</tr>
</tbody>
</table>

Feed rate: 7.1-12.1 kg·h⁻¹

When extrusion variable changed: +, increase; -, decrease; =, no change; NS, insignificant change; NR, not reported.
• **High shear.** High speeds and shallow flights create high pressures and temperatures that are needed to make breakfast cereals and expanded snack foods.

• **Medium shear.** For b readings, texturised proteins and semi-moist pet foods.

• **Low shear.** Deep flights and low speeds create low pressures for forming pasta, meat products and gums. Operating data for different types of extruder are given in Table 2.2.

### Table 2-2 Operating data for different types of extrude

*(Huack, 1988; Harper, 1978)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>High shear (kWh kg⁻¹)</th>
<th>Medium shear (kWh kg⁻¹)</th>
<th>Low shear (kWh kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net energy input to product</td>
<td>0.10–0.16</td>
<td>0.02–0.08</td>
<td>0.01–0.04</td>
</tr>
<tr>
<td>Barrel length diameter (L/D)</td>
<td>2–15</td>
<td>10–25</td>
<td>5–22</td>
</tr>
<tr>
<td>Screw speed (rpm)</td>
<td>&gt; 300</td>
<td>&gt; 200</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>Maximum barrel temperature (°C)</td>
<td>110–180</td>
<td>55–15</td>
<td>20–65</td>
</tr>
<tr>
<td>Maximum product temperature (°C)</td>
<td>149</td>
<td>79</td>
<td>52</td>
</tr>
<tr>
<td>Maximum barrel pressure (kPa)</td>
<td>4000–17 000</td>
<td>2000–4000</td>
<td>550–6000</td>
</tr>
<tr>
<td>Product moisture (%)</td>
<td>5–8</td>
<td>15–30</td>
<td>25–75</td>
</tr>
<tr>
<td>Product density (kg/m³)</td>
<td>32–160</td>
<td>160–500</td>
<td>320–800</td>
</tr>
</tbody>
</table>
2.3 Milk Separation or Cream Separation:

The cream separation is a very important unit operation in dairy industry. Centrifugal cream separation serves to make cream and skim milk:

- to obtain some cream from whey or sweet-cream buttermilk,
- to standardize milk and milk products to a desired fat content.

It is applied in the industrial manufacture of nearly all dairy products. Centrifugal separation is far quicker (hence, also more hygienic) and far more complete. This is achieved by

1. making it a flow-through process;
2. causing the fat globules to move very much faster by means of a high centrifugal acceleration;
3. by greatly limiting the distance over which the fat globules have to move.

Cream is usually separated from milk by the centrifugation process (Walstra et al., 2006).

2.3.1 Centrifugation

Sometimes gravity separation may be too slow because of the closeness of densities of the particle and the fluid, or because of the association forces holding components together, as in emulsions like whole milk. In that case centrifugation helps in separation of the components on the basis of differences in their densities.

- The centrifuge increases the forces on particles many fold.
- Thus the particles that do not settle readily or at all in gravity settlers can often be separated from fluids by centrifugal force.
- The relative settling velocities of small particles are not changed, but the disturbing effects of Brownian motion and free convection currents are overcome (Walstra et al., 2006).

2.3.1.1 Theory

Centrifugal force is generated when materials are rotated; the size of the force depends on the radius and speed of rotation and the density of the centrifuged material. In the separation of immiscible liquids, the denser liquid moves to the bowl wall and the lighter liquid is displaced to an inner annulus (Figure 2.8) (Fellows, 2000).

The thickness of the layers is determined by the density of the liquids, the pressure difference across the layers and the speed of rotation. A boundary region
between the liquids at a given centrifuge speed forms at a radius \( r_n \) where the hydrostatic pressure of the two layers is equal. This is termed the neutral zone and is important in equipment design to determine the position of feed and discharge pipes. It is found using:

\[
r_n^2 = \frac{\rho_A r_A^2 - \rho_B r_B^2}{\rho_A - \rho_B} \tag{2.1}
\]

Where \( \rho \) (kg /m \(^3\)) = density and \( r \) (m) = the radius. The subscripts A and B refer to the dense and light liquid layers respectively. If the purpose is to remove light liquid from a mass of heavier liquid (for example in cream separation from milk), the residence time in the outer layer exceeds that in the inner layer. This is achieved by using a smaller radius of the outer layer \( (r_1 \) in Figure 2.9) and hence reducing the radius of the neutral zone. Conversely, if a dense liquid is to be separated from a mass of lighter liquid (for example the removal of water from oils), the radius of the outer layer (and the neutral zone) is increased.

When particles are removed from liquids in centrifugal clarification, the particles move to the bowl wall under centrifugal force. If liquid flow is streamlined, the rate of movement is determined by the densities of the particles and liquid, the viscosity of the liquid and the speed of rotation (equation (2.2)). Separation under turbulent flow conditions is described by (Earle, 1983).

\[
Q = \frac{D^2 w^2 (\rho_s - \rho)V}{18\mu \ln(r_2/r_1)} \tag{2.2}
\]

Where \( w(2\pi N /60) \) = angular velocity, \( Q(\text{m}^3 \text{s}^{-1}) \) = volumetric flow rate, \( V(\text{m}^3) \) = operating volume of the centrifuge, \( D(\text{m}) \) = diameter of the particle, \( \rho_s (\text{kg m}^{-3}) \) = density of particles, \( \rho (\text{kg m}^{-3}) \) = density of liquid, \( \mu(\text{N s m}^{-2}) \) = viscosity of liquid, \( r_2(\text{m}) \) = radius of centrifuge bowl, \( r_1(\text{m}) \) = radius of liquid, \( N(\text{rev s}^{-1}) \) = speed of rotation. For a given particle diameter, the average residence time of a suspension equals the time taken for a particle to travel through the liquid to the centrifuge wall:

\[
t = \frac{V}{Q} \tag{2.3}
\]

Where \( t \) (s) = residence time. The flow rate can therefore be adjusted to retain a specific range of particle sizes (Fellows, 2000)
2.3.1.2 Equipment

The equipment using this principle of separation is known as a centrifuge. The centrifuges are used for:

- separation of immiscible liquids,
- clarification of liquids by removal of small amounts of solids, and
- for removal of solids from liquids.

Centrifuges are also used for centrifugal filtration, where the centrifugal force is used (not the pressure difference) to separate the solids through a filter medium. The major applications of the centrifuges are shown in Figure (2.7).

![Figure 2.7 Major applications of the centrifuges](image)

As can be observed from Figure (2.7) for cream separation, two types of centrifuges are used, namely, the tubular bowl centrifuge, and the disc bowl centrifuge (Mulder and Walstra, 1974).

2.3.1.2.1 Tubular bowl centrifuge:

The basic characteristic features of a tubular bowl centrifuge are as follows.

- It consists of a vertical cylinder (or bowl), typically 0.1-0.15 m in diameter and 0.75 m long.
- Rotates inside a stationary casing (15000-50000 rev/min depending on the diameter).
- Tubular bowl centrifuges, which develop about 13000xg force, are also known as super centrifuges.
- Feed liquor is introduced continuously at the base of the bowl and the two liquids are separated and discharged through a circular weir system into stationary outlets.
Some narrow centrifuges known as Ultra centrifuges have a diameter of 75 mm and very high speeds of about 60000 rev/min (Mulder and Walstra, 1974).

![Figure 2.8 A tubular bowl centrifuge](image1)

![Figure 2.9 Working principle of a tubular bowl centrifuge (Hemfort, 1983)](image2)

Separation of immiscible liquids: \( r_1 \), radius of dense phase outlet; \( r_2 \), radius of light phase outlet; \( r_n \), radius of neutral zone.

### 2.3.1.2 Disc bowl centrifuge

Disk centrifuges (Figure 2.10) are used in dairy processing (separation of cream from milk), and in the clarification of various liquids, like fruit juices and citrus oils. They consist of a centrifugal bowl 20-50 cm wide, with a series of cone disks. Perforated disks are used to facilitate the centrifugal separation of liquids of different density (e.g., cream/milk). The liquid feed mixture enters at the center of the bowl and it is separated by the centrifugal force into a light and a heavy stream, which are removed separately with special piping. Nozzle-discharge centrifuges are used when significant amounts of solid particles settle in the centrifugal field. They have small openings at the bottom sides of the bowl, through which the settled particles are removed continuously (Saravacos and Kostaropoulos, 2002).
The characteristic features of a disc bowl centrifuge are as follows:

- It consists of a conical bowl (0.2-1.2 m diameter), which contains a stack of inverted metal cones.
- The cones rotate at 2000-7000 rev/min.
- There is a fixed clearance between cones: 0.5-1.27 mm; and they have matching holes which form flow channels for liquid movement.
- Feed is introduced at the base of the disc stack.
- Due to the centrifugal force, the denser fraction moves towards the wall of the bowl, along the underside of the discs. The lighter fraction moves towards the Centre along the upper surfaces.

Both liquid streams are removed continuously by a weir system at the top in a similar way to the tubular bowl system (Mulder and Walstra, 1974).
Figure 2.11 A disc bowl centrifuge  

Figure 2.12 Working principle of a disc bowl centrifuge (Hemfort, 1983)

Figure 2.13 The basic principle of a so-called semi-open milk separator. The (revolving) bowl and the (non-revolving) machinery for supply and discharge are shown. In reality, the bowl contains a far greater number of discs (Mulder and Walstra, 1974).
Disc bowl and tubular centrifuges can have capacities even up to 150000 l/h.

Better separation is obtained by the disc bowl centrifuge due to the formation of thinner layers of liquid.

Periodic cleaning of deposited solids is required.

The disc bowl centrifuge, in addition to being widely used for separation of cream from whole milk, is also used for clarification of oils, coffee extracts and juices, and separation of starch-gluten (Mulder and Walstra, 1974).

**Domestic cream separator:**

Small capacity domestic cream separators working on the principle of disc bowl centrifuges are also available. Figure 2.14 shows such a domestic cream separator with its basic component parts. The separator is operated by hand with the help of a handle fixed to it (Mulder and Walstra, 1974).

![Figure 2.14 Domestic cream separator (Mulder and Walstra, 1974)](image)

**2.3.2 Continuous centrifugal separation of milk:**

**Clarification**

In a centrifugal clarifier, the milk is introduced into the separation channels at the outer edge of the disc stack, flows radially inwards through the channels towards the axis of rotation and leaves through the outlet at the top as illustrated in figure (2.15).
On the way through the disc stack the solid impurities are separated and thrown back along the undersides of the discs to the periphery of the clarifier bowl. There they are collected in the sediment space. As the milk passes along the full radial width of the discs, the time of passage also allows very small particles to be separated. The most typical difference between a centrifugal clarifier and a separator is the design of the disk stack – clarifier without distribution holes – and the number of outlets – clarifier one and separator two (Bylund, 1995).

**Separation**

In a centrifugal separator the disc stack is equipped with vertically aligned distribution holes. Figure 2.16 shows schematically how fat globules are separated from the milk in the disc stack of a centrifugal separator. A more detailed illustration of this phenomenon is shown in figure 2.17
Figure 2.16 A centrifugal separator bowl (Bylund, 1995).

Figure 2.17 (a) Sectional view of part of the disc stack, (b) Disc stack with distribution holes and caulks (Bylund, 1995).

The milk is introduced through vertically aligned distribution holes in the discs at a certain distance from the edge of the disc stack. Under the influence of centrifugal force the sediment and fat globules in the milk begin to settle radially outwards or
inwards in the separation channels, according to their density relative to that of the continuous medium (skim milk).

As in the clarifier, the high-density solid impurities in the milk will quickly settle outwards towards the periphery of the separator and collect in the sediment space. Sedimentation of solids is assisted by the fact that the skim milk in the channels in this case moves outwards towards the periphery of the disc stack.

The cream, i.e. the fat globules, has a lower density than the skim milk and therefore moves inwards in the channels, towards the axis of rotation. The cream continues to an axial outlet.

The skim milk moves outwards to the space outside the disc stack and from there through a channel between the top of the disc stack and the conical hood of the separator bowl to a concentric skim milk outlet (Bylund, 1995).

**Skimming efficiency**

*Separation efficiency* is generally the main concern in the manufacture of skim milk powder, in skimming cheese whey, etc.

The following are the main factors determining the creaming efficiency:

1. **The centrifugal acceleration** $R_w^2$: This is usually about 6000 $g$, where $g$ is the acceleration due to gravity.
2. **The distance over which the fat globules must move**. The separation therefore occurs over only about 0.5 mm.
3. **Time available for separation**: This results from the volume and the geometry of the part of the centrifuge in which separation occurs and from the flow rate.
4. **The size distribution of the fat globules**: The critical diameter of fat globules that are just recovered by centrifugation is about 0.7 m.
5. **Temperature**: Above all, temperature affects $h_p$, and also $r_i$, $r_p$, and, slightly, $d$. These variables can be lumped in an efficiency factor.
6. **Proper operation of the separator**: This implies no vibrations, no leakage, etc. (Walstraet et al, 2006).

The amount of fat that can be separated from milk depends on the design of the separator, the rate at which the milk flows through it, and the size distribution of the fat globules.

The smallest fat globules, normally $< 1$ µm, do not have time to rise at the specified flow rate but are carried out of the separator with the skim milk. The
remaining fat content in the skim milk normally lies between 0.04 and 0.07%, and
the skimming ability of the machine is then said to be 0.04 – 0.07.

The flow velocity through the separation channels will be reduced if the flow
rate through the machine is reduced. This gives the fat globules more time to rise and
be discharged through the cream outlet. The skimming efficiency of a separator
consequently increases with reduced throughput and vice versa (Bylund, 1995).

**Fat content of cream**

The whole milk supplied to the separator is discharged as two flows, skim
milk and cream, of which the cream normally represents about 10% of the total
throughput. The proportion discharged as cream determines the fat content of the
cream (Bylund, 1995).

### 2.3.3 Warm milk skimming

Milk skimming during pasteurization is the most common centrifugal
separator application in dairies. The purpose of the skimming process is to separate
the raw milk into skim milk and cream. The product temperature should normally be
kept between 113°F and 131°F (45°C and 55°C) in order to ensure optima skimming
efficiency. Skimming efficiency is influenced by the transport of whole milk, milk
storage temperature and time, seasonal variation, milk quality, mechanical treatment
and free air-content upstream from the separator.

Skimming efficiency is expressed as residual fat content in the skimmed
milk.

At rated capacity, Seital brand separators generally give a residual fat content in the range of:

- 0.03 - 0.05% measured by Gerber method
- 0.040 - 0.055% measured by Rose-Gottlieb method.

### 2.3.4 Cold milk skimming

Cold milk separation at > 39.2 °F (4°C) takes place in a number of processes
including:

- Cheese making process using unpasteurized milk
- Pre-standardization process (avoiding double heating treatment)
- High-quality cream production.

Cold milk separation enables significant savings in energy and thermal
equipment such as heat exchangers. Cold milk skimming efficiency is lower than for
warm milk, and cream concentration cannot exceed 40-42 %. Skimming efficiency improves by increasing temperature and/or reducing flow-rate.

Viscosity and other cream characteristics at low temperature require the use of a special hermetic separator (www.spxflow.com, 2017)

Figure 2.18 Separator bowl components (User’s manual, 2016).
2.3.5 Structure and principle of operation

1. The centrifuge consists of case with mechanical drive, drum, skim milk receiver, cream receiver, float, float bowl, milk receiver, and tap.
2. The following parts are installed in the case.
3. Mechanical drive is turning the drum. For reach the right work of separator please turn the handle with speed of 1 circle/second.
4. The principal driven element is the drum (fig.2.18). Separation of milk into cream and skim milk takes place inside the drum under centrifugal force. The drum consists of plate holder 1 with a set of aluminum plates 3, separating plate 4 with adjusting screw 7, lid 2, seal ring 5, nut 6.
5. The delivery, hereinafter “the dishware”, serves for warmed-up milk supply into the drum, and for cream and skim milk withdrawal out of the drum. The dishware (fig.2.18) consists of the milk receiver with a tap, a float bowl, a float, cream and skim milk receivers (User’s manual, 2016).
2.4 Computer Aided Design (CAD):

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations.

Computer-aided design is used in many fields. It’s use in designing electronic systems is known as electronic design automation, or EDA. In mechanical design it is known as mechanical design automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software. CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application specific conventions.

CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space (Yadav, 1996).

Computer Aided Design (CAD) is defined as the use of information technology (IT) in the Design process. A CAD system consists of IT hardware (H/W), specialized software (S/W) (depending on the particular area of application) and peripherals, which in certain applications are quite specialized.

The core of a CAD system is the S/W, which makes use of graphics for product representation; databases for storing the product model and drives the peripherals for product presentation. Its use does not change the nature of the design process but as the name states it aids the product designer. The designer is the main actor in the process, in all phases from problem identification to the implementation phase. The role of the CAD is in aiding him/her by providing:

- Accurately generated and easily modifiable graphical representation of the product. The user can nearly view the actual product on screen, make any modifications to it, and present his/her ideas on screen without any prototype, especially during the early stages of the design process.
Perform complex design analysis in short time. Implementing Finite Elements Analysis methods the user can perform.

Static, Dynamic and Natural Frequency analysis, Heat transfer analysis, Plastic analysis, Fluid flow analysis, Motion analysis, Tolerance analysis, Design optimization.

Record and recall information with consistency and speed. In particular the use of Product Data Management (PDM) systems can store the whole design and processing history of a certain product, for future reuse and upgrade (Bilalis, 2000).

2.4.1 MATLAB:

MATLAB is an interactive software which has been used recently in various areas of engineering and scientific applications. It is not a computer language in the normal sense but it does most of the work of a computer language. Writing a computer code is not a straightforward job, typically boring and time consuming for beginners. One attractive aspect of MATLAB is that it is relatively easy to learn. It is written on an intuitive basis and it does not require in-depth knowledge of operational principles of computer programming like compiling and linking in most other programming languages.

This could be regarded as a disadvantage since it prevents users from understanding the basic principles in computer programming. The interactive mode of MATLAB may reduce computational speed in some applications. The power of MATLAB is represented by the length and simplicity of the code. For example, one page of MATLAB code may be equivalent to many pages of other computer language source codes. Numerical calculation in MATLAB uses collections of well-written scientific/mathematical subroutines such as LINPACK and EISPACK. MATLAB provides Graphical User Interface (GUI) as well as three-dimensional graphical animation (Hunt et al, 2001).

The name MATLAB stands for MATrixLABoratory. MATLAB was written originally to provide easy access to matrix software developed by the LINPACK (linear system package) and EISPACK (Eigen system package) projects. MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming.
These factors make MATLAB an excellent tool for teaching and research. MATLAB has many advantages compared to conventional computer languages (e.g., C, FORTRAN) for solving technical problems. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. The software package has been commercially available since 1984 and is now considered as a standard tool at most universities and industries worldwide. It has powerful built-in routines that enable a very wide variety of computations. It also has easy to use graphics commands that make the visualization of results immediately available. Specific applications are collected in packages referred to as toolbox. There are toolboxes for signal processing, symbolic computation, control theory, simulation, optimization, and several other fields of applied science and engineering (Houcque, 2005).

2.4.2 Microsoft Visual Basic:

Is a powerful software development system for creating applications that run in Windows XP and Windows Vista.

With Visual Basic, you can do the following:

- Create applications with graphical windows, dialog boxes, and menus.
- Create applications that work with databases.
- Create Web applications and applications that use Internet technologies.
- Create applications that display graphics.

Visual Basic is a favorite tool among professional programmers. Its combination of visual design tools and BASIC programming language make it intuitive, allowing developers to create powerful real-world applications in a relatively short time.

Software refers to the programs that run on a computer. There are two general categories of software: operating systems and application software. An operating system or OS is a set of programs that manages the computer’s hardware devices and controls their processes. Windows XP, Windows Vista, MacOSX, and Linux are all operating systems (Gaddis, 2008).

Application software refers to programs that make the computer useful to the user. These programs, which are generally called applications, solve specific problems or
perform general operations that satisfy the needs of the user. Word processing, spreadsheet, and database packages are all examples of application software (Gaddis, 2008).

### 2.4.3 Programs and Programming Languages:

A program is a set of instructions a computer follows inorder to perform a task. A programming language is a special language used to write computer programs.

**What is a Program?** Computers are designed to follow instructions. A computer program is a set of instructions that enables the computer to solve a problem or perform a task.

**Programming Languages:** As mentioned earlier, a program is stored in memory as a series of binary numbers. These numbers are known as **machine language instructions**.

Programming languages, which use words instead of numbers, were invented to ease this task. Programmers can write their applications in programming language statements, and then use special software called a **compiler** to convert the program into machine language. Names of some popular recent programming languages are shown in Table 2-3. This list is only a small sample there are thousands of programming languages.

**Visual Basic** is more than just a programming language. It is a programming environment, with tools for creating screen elements and programming language statements. Although Visual Basic, as a whole, is radically different from the original BASIC programming language, its programming statements are similar (Gaddis, 2008).
### Table 2-3 Popular programming languages (Gaddis, 2008)

<table>
<thead>
<tr>
<th>Language</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VisualBasic, C#</td>
<td>Popular programming languages for building Windows and Web applications. Use a graphical user interface.</td>
</tr>
<tr>
<td>C, C++</td>
<td>Flexible and powerful programming language that runs on many different computersystems. Often used to teach object-oriented programming.</td>
</tr>
<tr>
<td>Java</td>
<td>Powerful advanced programming languages that emphasize flexibility and fast running times. C++ is also object-oriented.</td>
</tr>
<tr>
<td>Python</td>
<td>Simple, yet powerful programming language used for graphics and small applications.</td>
</tr>
<tr>
<td>PHP</td>
<td>Programming language used for creating interactive Websites.</td>
</tr>
</tbody>
</table>

### 2.4.4 Procedural and Object-Oriented Programming:

There are primarily two methods of programming used today: procedural programming and object-oriented programming.

**Procedural Programming:** The earliest programming languages were procedural. Procedural programming means that a program is made of one or more procedures. A procedure is a set of programming language statements that are executed by the computer. The statements might gather input from the user, manipulate information stored in the computer’s memory, perform calculations, or any other operation necessary to complete its task.

Procedural programming was the standard when users were interacting with text-based computer terminals (Gaddis, 2008).

**Object-Oriented Programming**

Object-oriented programming or OOP: is an industry standard model for designing and coding programs. When designing applications, designers use real-world objects to express patterns, called classes in software.
In Visual Basic, classes are used to describe the objects that appear on the screen. When a program runs, these objects are created and displayed.

**Graphical User Interface:** In text-based environments using procedural programs, the user responds to the program. Modern operating systems, such as the Windows family, use a graphical user interface, or GUI (pronounced gooey). Although GUIs have made programs friendlier and easier to interact with, they have not simplified the task of programming. GUIs require on-screen elements such as windows, dialog boxes, buttons, and menus. The program must handle the user’s interactions with these on-screen elements, in any order the user might choose to select them. No longer does the user respond to a program—now the program responds to a user.

GUIs have helped influence the shift from procedural programming to object-oriented programming. Whereas procedural programming is centered on creating procedures, object-oriented programming is centered on creating objects. An object is a programming element that contains data and actions. The data contained in an object is known as its attributes. In Visual Basic, an object’s attributes are called properties. The actions that an object performs are known as the object’s methods. The object is, conceptually, a self-contained unit consisting of data (properties) and actions (methods) (Gaddis, 2008).

**2.4.5 More about Controls and Programming:**

As a Visual Basic programmer, you must design and create the two major components of an application: the GUI elements (forms and other controls) and the programming statements that respond to and/or perform actions (event procedures).

While creating a Visual Basic application, you will spend much of your time doing three things: creating the GUI elements that make up the application’s user interface, setting the properties of the GUI elements, and writing programming language statements that respond to events and perform other operations. In this section, we take a closer look at these aspects of Visual Basic programming.

**Visual Basic Controls:** In the previous section, you saw examples of several GUI elements, or controls. Visual Basic provides a wide assortment of controls for gathering input, displaying information, selecting values, showing graphics, and more. Table 2-4 lists some of the commonly used controls (Gaddis, 2008).
Table 2-4 Visual Basic controls (Gaddis, 2008)

<table>
<thead>
<tr>
<th>Control Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CheckBox</td>
<td>A box that is checked or unchecked when clicked with the mouse</td>
</tr>
<tr>
<td>ComboBox</td>
<td>A control that is the combination of a ListBox and a TextBox</td>
</tr>
<tr>
<td>Button</td>
<td>A rectangular button-shaped object that performs an action when clicked with the mouse</td>
</tr>
<tr>
<td>Form</td>
<td>A window on which other controls may be placed</td>
</tr>
<tr>
<td>GroupBox</td>
<td>A rectangular border that functions as a container for other controls</td>
</tr>
<tr>
<td>HScrollBar</td>
<td>A horizontal scroll bar that, when moved with the mouse, increases or decreases a value</td>
</tr>
<tr>
<td>Label</td>
<td>A box that displays text that cannot be changed or entered by the user</td>
</tr>
<tr>
<td>ListBox</td>
<td>A box containing a list of items</td>
</tr>
<tr>
<td>RadioButton</td>
<td>A round button that is either selected or deselected when clicked with the mouse</td>
</tr>
<tr>
<td>PictureBox</td>
<td>A control that displays a graphic image</td>
</tr>
<tr>
<td>TextBox</td>
<td>A rectangular area in which the user can enter text, or the program can display text</td>
</tr>
<tr>
<td>VScrollBar</td>
<td>A vertical scroll bar that, when moved with the mouse, increases or decreases a value.</td>
</tr>
</tbody>
</table>

2.4.6 Types of Programming Language:

There are three types of programming language:

– Machine language (Low-level language)
– Assembly language (Low-level language)
– High-level language

Low-level languages are closer to the language used by a computer, while high-level languages are closer to human languages.
2.4.6.1 Machine Language:
• Machine language is a collection of binary digits or bits that the computer reads and interprets.
• Machine languages are the only languages understood by computers.
• While easily understood by computers, machine languages are almost impossible for humans to use because they consist entirely of numbers.

Machine Language 169 1 160 0 153 0 128 153 0 129 153 130 153 0 131 200 208 241 96

High level language 5 FOR I=1 TO 1000: PRINT "A".;: NEXT I

2.4.6.2 Assembly Language:
• A program written in assembly language consists of a series of instructions mnemonics that correspond to a stream of executable instructions, when translated by an assembler that can be loaded into memory and executed.
• Assembly languages use keywords and symbols, much like English, to form a programming language but at the same time introduce a new problem.
• The problem is that the computer doesn't understand the assembly code, so we need a way to convert it to machine code, which the computer does understand.
• Assembly language programs are translated into machine language by a program called an assembler

Examples:
– Machine language: 10110000 01100001
– Assembly language: mov a1, #061h – Meaning: Move the hexadecimal value 61 (97 decimal) into the processor register named "a1".

2.4.6.3 High Level Language:
• High-level languages allow us to write computer code using instructions resembling everyday spoken language (for example: print, if, while) which are then translated into machine language to be executed.
• Programs written in a high-level language need to be translated into machine language before they can be executed.
• Some programming languages use a compiler to perform this translation and others use an interpreter.

Examples of High-level Language:
• ADA
• C
• C++
• JAVA
• BASIC
• COBOL
• PASCAL
• PHYTON

Table 2-5 Comparison between type of languages (FTMS, 2018)

<table>
<thead>
<tr>
<th></th>
<th>Machine Language</th>
<th>Assembly Language</th>
<th>High-level Languages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to execute</td>
<td>Since it is the basic language of the computer, it does not require any translation, and hence ensures better machine efficiency. This means the programs run faster.</td>
<td>A program called an 'assembler' is required to convert the program into machine language. Thus, it takes longer to execute than a machine language program.</td>
<td>A program called a compiler or interpreter is required to convert the program into machine language. Thus, it takes more time for a computer to execute.</td>
</tr>
<tr>
<td>Time to develop</td>
<td>Needs a lot of skill, as instructions are very lengthy and complex. Thus, it takes more time to program.</td>
<td>Simpler to use than machine language, though instruction codes must be memorized. It takes less time to develop programs as compared to machine language.</td>
<td>Easiest to use. Takes less time to develop programs and, hence, ensures better program efficiency.</td>
</tr>
</tbody>
</table>

2.4.7 BASIC:
• Short for Beginner's All-purpose Symbolic Instruction Code.
• Developed in the 1950s for teaching University students to program and provided with every self-respecting personal computer in the 1980s.
• BASIC has been the first programming language for many programmers.
• It is also the foundation for Visual Basic.
Example:
PRINT "Hello world!"

Visual Basic:
• A programming language and environment developed by Microsoft.
• Based on the BASIC language, Visual Basic was one of the first products to provide a graphical programming environment and a paint metaphor for developing user interfaces.

Example:
Msg.Box "Hello, World!"

C
• Developed by Dennis Ritchie at Bell Labs in the mid-1970s.
• C is much closer to assembly language than are most other high-level languages.
• The first major program written in C was the UNIX operating system.
• The low-level nature of C, however, can make the language difficult to use for some types of applications.

Example:
#include <stdio.h>
int main(void) { printf("hello, world\n"); return 0; }

C++
• A high-level programming language developed by Bjarne Stroustrup at Bell Labs.
• C++ adds object-oriented features to its predecessor, C.
• C++ is one of the most popular programming language for graphical applications, such as those that run in Windows and Macintosh environments.

C++
Example:
#include <iostream>
int main() { std::cout<< "Hello World!" <<std::endl; return 0; }

Pascal
• A high-level programming language developed by Niklaus Wirth in the late 1960s.
• The language is named after Blaise Pascal, a seventeenth-century French mathematician who constructed one of the first mechanical adding machines.
• It is a popular teaching language.

Example:
Program HelloWorld(output); begin writeln('Hello, World!') end.
Java
• A high-level programming language developed by Sun Microsystems.
• Java was originally called OAK, and was designed for handheld devices and set-top boxes.
• Oak was unsuccessful so in 1995 Sun changed the name to Java and modified the language to take advantage of the burgeoning World Wide Web.
• Java is a general purpose programming language with a number of features that make the language well suited for use on the World Wide Web.

Example:
* * Outputs "Hello, World!" and then exits */ public class Hello World { public static void main (String [] args) { System.out.print.ln("Hello, World!"); }}

2.4.8 Choosing a Programming Language:
Before you decide on what language to use, you should consider the following:
• your server platform
• the server software you run
• your budget
• previous experience in programming
• the database you have chosen for your backend (FTMS, 2018).

2.4.9 The Visual Basic Programming Language:
Visual Basic is a programming language that you can use to create interactive Web pages and to write Web-based applications that run on Web servers. Web servers are the computers that “serve up” content when you request to view Web pages. An online bookstore and an online course registration system are examples of Web-based applications. Visual Basic is also used to develop Windows-based stand-alone enterprise applications (programs that help manage data and run a business).

What makes Visual Basic especially useful is that it is an object-oriented programming language. The term object-oriented encompasses a number of concepts explained later in this chapter and throughout this book. For now, all you need to know is that an object-oriented programming language is modular in nature,
allowing the programmer to build a program from reusable parts of programs called classes, objects, and methods (Smith, 2011).

When Visual Basic was introduced by Microsoft in 1991, it was described as the perfect programming language because it allowed programmers to easily create applications that include a graphical user interface (GUI). A GUI allows users to interact with programs by using a mouse to point, drag, or click.

2.4.9.1 Three Types of Visual Basic Programs:

Visual Basic programs can be written as Web applications, Windows applications, or console applications. A Web application is a program that runs on the World Wide Web and is available to end users on any platform (e.g., Windows, Mac, Linux). A Windows application is a program, such as Microsoft Word or Excel, that runs on a Windows system. A console application is a program, without a GUI, that executes in a console window and produces text-based output.

Visual Basic programmers often use the Microsoft Visual Studio Integrated Development Environment (IDE) when they write programs (Smith, 2011).

2.4.9.2 An Introduction to Object-Oriented Terminology:

To fully understand the term object-oriented, you need to know a little about procedural programming. Procedural programming is a style of programming that is older than object-oriented programming (Smith, 2011).

Procedural programs consist of statements that the computer runs or executes. Many of the statements make calls (a request to run or execute) to groups of other statements that are known as procedures, modules, methods, or functions. These programs are known as “procedural” because they perform a sequence of procedures.

Procedural programming focuses on writing code that takes some data (for example, quarterly sales figures), performs a specific task using the data (for example, adding up the sales figures), and then produces output (for example, a sales report). When people who use procedural programs (the users) decide that they want their programs to do something slightly different, a programmer must revise the program code, taking great care not to introduce errors into the logic of the program.

Today, we need computer programs that are flexible and easy to revise. Object-oriented programming languages, including Visual Basic, were introduced to meet this need. In object-oriented programming, the programmer can focus on the
data that he or she wants to manipulate, rather than the individual lines of code required to manipulate that data (although those individual lines still must eventually be written). An object-oriented program is made up of a collection of interacting objects (Smith, 2011).
Chapter Three

3. Materials and Methods

This Chapter presents the overall materials and methodology for this work, includes a mathematical model (or engineering equations) that relevant to the calculation design of single screw extruder and milk separator, the data used to evaluate the computer program. Moreover, Matlab language and Visual Basic Studio background and the computer program description as shown in Figure 3.1.

Figure 3.1 The research methodology flowchart
3.1 Materials

Data for design calculations of single screw extruder and milk separator were collected from (Antipov et al, 2001; Panfilov and Urakov, 1999) and represented in tables 3-1 and 3-2.

Table 3-1: Basic values of the various parameters for extruder design calculations

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice hole’s surface diameters (R, r),</td>
<td>m</td>
<td>(8.4, 3.3) *10^{-3}</td>
</tr>
<tr>
<td>length of orifice cannell (L1),</td>
<td>m</td>
<td>28*10^{-3}</td>
</tr>
<tr>
<td>Step of the screw (S),</td>
<td>m</td>
<td>16*10^{-3}</td>
</tr>
<tr>
<td>Diameter of internal surface of the cylinder (DK),</td>
<td>m</td>
<td>91*10^{-3}</td>
</tr>
<tr>
<td>Highest of screw cannell (H),</td>
<td>m</td>
<td>15.5*10^{-3}</td>
</tr>
<tr>
<td>Number refers to the shape of orifice hole, for</td>
<td></td>
<td></td>
</tr>
<tr>
<td>identify the equation of finding (n) Kf : n&gt;1 for</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ring’s hole; n&lt;1 for cone hole.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic viscosity of raw material(µ),</td>
<td>Pa* sec</td>
<td>1.03*10^{6}</td>
</tr>
<tr>
<td>Angle of screw head line(Ø),</td>
<td>°</td>
<td>8</td>
</tr>
<tr>
<td>Rotation of the screw shaft (ω),</td>
<td>sec^{-1}</td>
<td>1.2</td>
</tr>
<tr>
<td>Width of screw cannell (B),</td>
<td>m</td>
<td>14*10^{-3}</td>
</tr>
</tbody>
</table>
### Table 3-2: Basic values of the various parameters for Milk separator design calculation

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotation of separator cylinder (ω),</td>
<td>rpm</td>
<td>500</td>
</tr>
<tr>
<td>Diameter of separator main column (dₙ),</td>
<td>m</td>
<td>0.04</td>
</tr>
<tr>
<td>Number of dishes (Z),</td>
<td>-</td>
<td>130-150</td>
</tr>
<tr>
<td>Dishesangle (α),</td>
<td>°</td>
<td>45-60</td>
</tr>
<tr>
<td>Outer diameter of dishes (Rₒ),</td>
<td>m</td>
<td>0.18</td>
</tr>
<tr>
<td>Inner diameter of dishes (Rᵢ),</td>
<td>m</td>
<td>0.06</td>
</tr>
<tr>
<td>Fatty mass in skimmed milk (m),</td>
<td>%</td>
<td>0.01</td>
</tr>
<tr>
<td>Volume of interring raw milk (V),</td>
<td>m³</td>
<td>4.8</td>
</tr>
<tr>
<td>The inner diameter of the milk ball (rₙ),</td>
<td>m</td>
<td>0.015</td>
</tr>
<tr>
<td>Volumetric concentration of suspended parts in milk (a)</td>
<td>%</td>
<td>0.3</td>
</tr>
<tr>
<td>Plasticity of separator column metal (E),</td>
<td>N/m</td>
<td>2×10¹⁴</td>
</tr>
<tr>
<td>The distance between the upper and lower bearings (L),</td>
<td>m</td>
<td>0.57</td>
</tr>
<tr>
<td>The distance between the upper bearing and the center of gravity (C),</td>
<td>m</td>
<td>0.30</td>
</tr>
<tr>
<td>Motorefficiency (ηₑ),</td>
<td>-</td>
<td>0.95-0.92</td>
</tr>
<tr>
<td>Flow efficiency (ηₑ),</td>
<td>-</td>
<td>0.95-0.92</td>
</tr>
<tr>
<td>Air density (ρₑ),</td>
<td>kg/m³</td>
<td>1.23</td>
</tr>
<tr>
<td>Friction coefficient (µ),</td>
<td>-</td>
<td>0.03</td>
</tr>
<tr>
<td>Mass of the circulatory part of the separator with milk (G),</td>
<td>kg</td>
<td>109</td>
</tr>
<tr>
<td>Gravity(g),</td>
<td>m/sec²</td>
<td>9.8</td>
</tr>
<tr>
<td>Mass of the cylinder(mₑ),</td>
<td>kg</td>
<td>81</td>
</tr>
<tr>
<td>Correction coefficient(β),</td>
<td>-</td>
<td>(0.2-0.5)</td>
</tr>
</tbody>
</table>
3.2 Methods

3.2.1 Method of design calculation of single screw extruder (Panfilov and Urakov, 1999)

3.2.1.1 Method of Single Screw Extruder Design Calculations:

Flowrate of the orifice, m$^3$/sec

$$Q_f = \left( \frac{K_f}{\mu} \right) \Delta p$$ ................................. (3.1)

Where:

$K_f$ – Dimension coefficient of the shaping organ for the orifice with ring hole, m$^3$

$$K_f = \frac{(\pi D + h) \cdot h^3}{12L_1}$$ ................................. (3.2)

Where:

$D$ – Average of the ring orifice hole’s diameter, m

$$D = 2R - h$$

Here:

$h$ –Width of the ring orifice surface, m

$$h = R - r$$

$K_f$ - For the orifice with cone shape, m$^3$/sec

$$K_f = \frac{3\pi \cdot R^3 \cdot r^3 \cdot (R - r)}{8L_1 \cdot (R^2 - r^2)}$$ ................................. (3.3)

Flowrate of the screw shaft, m$^3$/sec

$$Q_T = K_{T1} \cdot \omega - \left( \frac{K_{T2}}{\mu} \right) \Delta P$$ ................................. (3.4)

$K_{T1}, K_{T2}$- Geometrical coefficient of the screw shaft, m$^3$

$$K_{T1} = \frac{\pi \cdot D k \cdot B \cdot H \cdot \cos \theta}{2}$$ ................................. (3.5)
\[ K_{T2} = \frac{B \cdot H^3}{12 \cdot L_2} \] .................................. (3.6)

Where:

\[ L_2 = \text{Length of screw cannel, m} \]

\[ L_2 = \sqrt{s^2 + [\pi (Dk - H)]^2} \] .................................. (3.7)

The pressure made by extruder, Pa

\[ \Delta P = \frac{\mu K_{T1} + \omega}{(K_{T2} + K_f)} \] .................................. (3.8)

Extruder productivity, m³/sec

\[ Q_{ex} = \frac{K_{T1} + K_f}{(K_{T2} + K_f)} \cdot \omega \] .................................. (3.9)
3.2.1.2 The flowchart (Algorithm) of single screw extruder design calculations:

START

Read R, r, L₁, S, Dk, H, n, B, Ø, μ, ω

h = R-r

D = 2R - h

\[ L_2 = \sqrt{s^2 + [\pi(Dk-H)]^2} \]

\[ K_f = \frac{(\pi D + h) * h^3}{12L_1} \]

\[ K_T = \frac{3\pi * R^3 * r^3 * (R-r)}{8L_1 * (R^3 - r^3)} \]

\[ K_{T1} = \frac{\pi * Dk * B * H * \cos \theta}{2} \]

\[ K_{T2} = \frac{B * H^3}{12 * L_2} \]

\[ \Delta P = \frac{\mu * K_{T1} * \omega}{(K_{T2} + K_f)} \]

\[ Q_f = \left( \frac{K_f}{\mu} \right) * \Delta p \]

\[ Q_T = K_{T1} * \omega - \left( \frac{K_{T2}}{\mu} \right) \]

\[ Q_{ex} = \frac{K_{T1} * K_f}{(K_{T2} + K_f)} * \omega \]

RING'S CONE

\[ n > 1 \]

END

Figure 3.2 Flowchart of single screw extruder design calculations
3.2.2 Method of design calculation of milk separator (Antipov et al., 2001) and (Panfilov and Urakov, 1999)

3.2.2.1 Method of Milk Separator Design Calculations:

Cream separator Productivity (\( \Pi \)) \( L/h \)

\[
\Pi = \frac{10^{-6} \beta \cdot w^2 \cdot Z \cdot \tan(\alpha) \cdot (R_B^3 - R_S^3) \cdot d^2 \cdot (\rho - \rho_0)}{4 \cdot \text{milk}}
\]  

……………… (3.10)

Sizes of fatty balls:

\[
d = \frac{m}{0.04} + 0.05
\]  

……………… (3.11)

Pressure of the outlet milk from separator (p), Pa

\[
P = \frac{\rho}{50000} \cdot (R_o^2 - r_k^2)
\]  

……………… (3.12)

Continuous operation time between discharges (\( \tau \)), sec

\[
\tau = \frac{0.1 + v}{\Pi \cdot a}
\]  

……………… (3.13)

The critical rotational frequency of the separator column (\( W_{KP} \)), s\(^{-1}\). Is the speed at which the column crashes

\[
W_{KP} = \frac{L}{(L-C) \cdot \sqrt{K/mg}}
\]  

……………… (3.14)

\[
K = \frac{3 \cdot E \cdot I}{c^2 \cdot (c+L)}
\]  

……………… (3.15)

Where as:

k – The force that deforms the column on one meter for the tight-fitting shaft (without installation), (N/m)

\[
I = 0.05 \cdot d_c^4
\]

The power of the electric motor of the separator when working continuously (N), Kwt

\[
N = \frac{1.2 \cdot (N_1 + N_2 + N_3)}{\eta_m}
\]  

……………… (3.16)

The consume power of milk from the separator at excessive pressure (\( N_1 \)), Kwt

\[
N_1 = \frac{\Pi \cdot p}{\eta \cdot 1000}
\]  

……………… (3.17)

The necessary power to resist the friction force of the cylinder with air (\( N_2 \)), Kwt

\[
N_2 = 1.8 \cdot 10^{-6} \cdot F \cdot \rho_a \cdot V_g^3
\]  

……………… (3.18)

Surface area of cylinder (F), m\(^2\)
\[ F = \frac{\pi (R_o^2 - R_i^2)}{\cos(\alpha)} + 0.4 \times 10^{-3} \times R_o \times Z \quad (3.19) \]

Speed of cylinder rotation \((v_g)\), m/sec

\[ V_g = \frac{\pi \times w \times R_o}{30} \quad (3.20) \]

The consume power to resist friction in bearings \((N_3)\), Kwt

\[ N_3 = 10^{-3} \times \mu \times G \times g \times V_m \quad (3.21) \]

Speed of column rotation \((V_m)\), m/sec

\[ V_m = \frac{\pi \times w \times d_c}{60} \quad (3.22) \]
3.2.1.2 The flowchart (Algorithm) of milk separator design calculation:

START

Read Z, G,L,R₀,Rᵣ, a, g,m,g,
E,C,P, ω, β, α, ρ, [μ,l]m , m,

P = \frac{ρ}{50000} * (R₀² - rₖ²)

\Pi = 10^{-6} * β * w² * Z * \tan(α) * (Rᵦ³ - Rₛ³) * d² * (ρ - ρ₀)

\frac{\tau}{\Pi * a}

I=0.05 *d_c^4

K = \frac{3 * E * I}{\pi² / (c _⊥ r)}

W_KP = \frac{L}{(L - C) * \sqrt{K/mg}}

N₁ = \frac{\Pi * p}{\varpi * 1000}

F = \frac{\pi * (R₀² - Rᵣ²)}{\cos(α)} + 0.4 * 10^{-3} * R₀ * Z

N₂ = 1.8*10⁶ * T * ρₐ * V_g^3

V_m = \frac{\pi * w * d_c}{60}

N₃ = 10^{-8} * μ * G * g * V_m

P,π, d,τ, W_KP, k, I,
F, V_g, V_m, N ,N₁,

End

Figure 3.3 Flowchart of milk separator design calculations
3.3 MATLAB Programming:

This section is intended for those who want to use basics of MATLAB programming language. Even with a limited knowledge of this language a programmer can write his/her own computer code for solving problems that are complex enough to be solved by other means.

3.3.1 The Command Window

You can start MATLAB by double clicking on the MATLAB icon that should be on the desktop of your computer. This brings up the window called the Command Window. This window allows a user to enter simple commands. To clear the Command Window type CLC and next press the Enter or Return key. To perform a simple computations type a command and next press the Enter or Return key.

The MATLAB command interface shows up at the start of MATLAB in the form shown in Figure (3.4).

The main elements of this command interface are:

1. the command window,
2. the command-history window,
3. the current directory window or (hidden in this view) the workspace (variable window),
4. the file information window,
5. the icon toolbar with the choice menu for the current directory,
6. the shortcut toolbar,
7. the start button.
3.3.2 The m-file

Files that contain a computer code are called the m-files. There are two kinds of m-files: the script files and the function files. Script files do not take the input arguments or return the output arguments. The function files may take input arguments or return output arguments.

To make the m-file click on File next select New and click on M-File from the pull-down menu. You will be presented with the MATLAB Editor/Debugger screen.
Here you will type your code, can make changes, etc. Once you are done with typing, click on File, in the MATLAB Editor/Debugger screen and select Save As…. Chose a name for your file, e.g. (Extruder .m) and click on Save. Make sure that your file is saved in the directory that is in MATLAB's search path.

If you have at least two files with duplicated names, then the one that occurs first in MATLAB's search path will be executed.

To open the m-file from within the Command Window type edit extruder and then press Enter or Return key. (MATLAB has built-in-m-file editor designed specifically for this purpose). This can be accessed using file menu:

![MATLAB Command Window](image)

**Figure 3.6 How to open m-file editor window (Mirza, 2006)**

By clicking at the file – New – m-file item, the m-file editor window pops up:
3.3.3 Arithmetic Operators

The evaluation of expressions is achieved by means of arithmetic operators. The arithmetic operations on two scalar constants or variables are shown in Table 3-3. Operators operate on operands (a and b in the table) (Hahn and Valentine, 2007).

Table 3-3 Arithmetic operations between two scalars (Hahn and Valentine, 2007)

<table>
<thead>
<tr>
<th>Operation</th>
<th>Algebraic form</th>
<th>MATLAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition</td>
<td>a + b</td>
<td>a + b</td>
</tr>
<tr>
<td>Subtraction</td>
<td>a - b</td>
<td>a - b</td>
</tr>
<tr>
<td>Multiplication</td>
<td>a * b</td>
<td>a * b</td>
</tr>
<tr>
<td>Right division</td>
<td>a/b</td>
<td>a/b</td>
</tr>
<tr>
<td>Left division</td>
<td>b/a</td>
<td>a \ b</td>
</tr>
<tr>
<td>Power</td>
<td>a^b</td>
<td>a ^ b</td>
</tr>
</tbody>
</table>
### Table 3-4 Mathematical functions (Hahn and Valentine, 2007)

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sin, sinh</td>
<td>Sine and hyperbolic sine</td>
</tr>
<tr>
<td>sqrt</td>
<td>Square root</td>
</tr>
<tr>
<td>tan, tanh</td>
<td>Tangent and hyperbolic tangent</td>
</tr>
<tr>
<td>cos, cosh</td>
<td>Cosine and hyperbolic cosine</td>
</tr>
<tr>
<td>exp</td>
<td>Exponential</td>
</tr>
</tbody>
</table>

#### 3.4 Visual Basic Programming

Visual Basic is just one of dozens of programming languages, but it’s one of the best and most successful. It’s one of the most popular languages in the world. It’s popular with business and in education. Visual Basic is simple, the commands are straightforward, and the basics are easy to grasp. With it you can write and run a program on your first day. Once you have the fundamentals, you can write programs of your own design. It’s powerful enough to take on almost any development project.

##### 3.4.1 Graphical User Interface Programs:

A Graphical User Interface (GUI) allows users to interact with programs by using a mouse to point, drag, or click. To create a GUI Visual Basic program, you must learn to use Microsoft Visual Studio, which is a programming environment made up of several languages, including Visual Basic, C++, C#, and J# (Smith, 2011).

GUI programs are referred to as event-driven or event-based because they respond to user-initiated events, such as a mouse click. Within a GUI program, an event listener waits for an event to occur and then responds to it. An event listener is actually a procedure that contains Visual Basic code that executes when a particular event occurs. In response to the event, the event listener executes. In order to create full-blown event-driven programs that make use of a GUI, you learn to use just a few of the many GUI controls that are included in Visual Basic, such as a button, a textbox, a label, and a form.

The Visual Studio Integrated Development Environment Visual Basic is one of the languages in the integrated software development environment called Microsoft Visual Studio. This environment is referred to as an integrated development
environment (IDE) because it includes not only programming languages but also the tools needed to build forms and to test and debug programs. A form is a rectangular area of a screen that serves as a user interface to a program. A form usually includes several elements, such as a title bar, a menu bar, and controls (Smith, 2011).

3.4.2 To Create Visual Studio IDE:

Click the Start button on the taskbar, click All Programs, and then click Microsoft Visual Studio 2010. The Visual Studio Start Page window appears as shown in Figure (3.8).

![Visual Studio Start Page](image)

**Figure 3.8 Visual Studio Start Page (Smith, 2011)**

As shown in Figure (3.8), the title bar at the top of the window contains the name of the window, a system menu, and buttons that you can use to minimize, maximize, or close the window. Below the title bar is the menu bar, which includes 10 menus: File, Edit, View, Debug, Team, Data, Tools, Test, Window, and Help. Each menu contains its own list of commands. The menu bar in Visual Studio is dynamic, which means the menus and commands change when you work on different tasks. Beneath the menu bar is the Start Page window. The Start Page allows you to open an existing project or create a new one by clicking on one of the projects listed.
in Recent Projects or clicking on Open Project or New Project. The Start Page is replaced when you open and work on a project. To the right of the Start Page window is the Solution Explorer window. The Solution Explorer displays the files that are included in the project you are working on. In Figure (3.8), the Solution Explorer is empty (Smith, 2011).

3.4.3 The Designer Window:

Two windows used when working in the Visual Studio IDE. The Designer window was used for designing forms, and the Code window was used for entering the source code that makes up the program, or solution. In Figure (3.9), notice that the form named Form1 is displayed in the Designer window. The Visual Basic Toolbox is also shown in Figure (3.9), to the left of the Designer window. The Visual Basic Toolbox contains the controls you add to a form, such as textboxes, buttons, and labels. A control is an object on a form that enables the user to interact with the solution. For example, the “Yes” button is a control.

![Visual Studio Designer window](image)

Figure (3.9) Visual Studio Designer window (Smith, 2011)

Two Forms were created using dragged objects, called controls, from the Toolbox and placed them on the form. There are many label controls and three button controls on these Forms. Label controls simply display text. The Code Window in addition to designing forms, you must also write code in the Code window, so that
the controls on the form actually do something when the program executes. To switch from the Designer window to the Code window, click View on the menu bar, and then click Code. The Code window is shown in Figure (3.10).

![Visual Studio Code window](image)

**Figure 3.10  Visual Studio Code window (Smith, 2011)**

In Figure (3.10), notice the procedure headers, which begin with Sub btnYes_Click and Sub btnNo_Click. Also, notice the procedure footers, End Sub. The headers mark the beginning of Visual Basic procedures (subroutines) that execute when either the “Yes” or “No” button is clicked on the form (Smith, 2011).

### 3.4.4 Design-Time and Run-Time Operating Modes:

Visual Studio has three modes of operation: design mode, run mode, and break mode. Design mode is for creating and modifying a program. Run mode is for testing a program by running it. Break mode is for debugging large programs. In run mode, the program is running (executing) (Smith, 2011).

63
3.4.5 Creating a Visual Basic IDE Program:

A Visual Basic GUI program was created. This program asks a user to enter the calculations data (inputs), which the program then calculates and displays the results.

Microsoft Visual Studio was opened. On the Start Page, click New Project. The New Project dialog box opens.

Click Windows Forms Application, and then click the OK button. The new project’s Visual Studio Designer window opens. The Solution Explorer window tells you that, by default, this solution is named WindowsApplication1.

To give the solution a more meaningful name, click the name WindowsApplication1 in the Solution Explorer window to select it, and then right-click the name. A pop-up menu opens.

On the pop-up menu, click Rename, and then press the Enter key. In the Solution Explorer window, you can also see the form file named Form1.vb. We will not change this name (Smith, 2011).

Figure 3.11 Program form and controls (Smith, 2011)
Chapter Four

4. Results and Discussion

4.1 An Overview

This chapter presents the results and discussions of design calculations of single screw extruder and milk separator using manual, MATLAB and Visual Basic programs.

4.1.1 Manual design calculations results for extruder:

Flow rate of the orifice, m$^3$/sec:

$$Q_f = \left( \frac{K_f}{\mu} \right) \Delta p$$

$K_f$ –Dimension coefficient of the shaping organ with ring hole, m$^3$:

$$K_f = \frac{(\pi D + h) \cdot h^3}{12L_1}$$

D – Average of the ring’s hole diameter, m.

$$D=2*8.4 \cdot 10^{-3} - 5.1 \cdot 10^{-3} = 0.0117 \text{ m}$$

$h$ –Width of the ring hole’s surface ,m.

$$h = 8.4 \cdot 10^{-3} - 3.3 \cdot 10^{-3} = 5.1 \cdot 10^{-3} \text{ m}$$

$$K_f = \left( \frac{\pi \cdot 0.0117 + 5.1 \cdot 10^{-3}}{12 \cdot 28 \cdot 10^{-3}} \right) = 1.652 \cdot 10^{-8} \text{ m}^3$$

$K_f$ - For cone’s hole, m$^3$.

$$K_f = \left( \frac{3\pi (8.4 \cdot 10^{-3})^3 (3.3 \cdot 10^{-3})^3 - (8.4 \cdot 10^{-3} - 3.3 \cdot 10^{-3})}{8 (8.4 \cdot 10^{-3})^3 \cdot (3.3 \cdot 10^{-3})^3} \right) = 8.209 \cdot 10^{-9} \text{ m}^3$$

Flowrate of the screw shaft, m$^3$/sec:

$$Q_T = K_{T1} \cdot \omega - \left( \frac{K_{T2}}{\mu} \right) \Delta P$$

$K_{T1}, K_{T2}$ - Geometrical coefficient of the screw shaft, m$^3$:

$$K_{T1} = \pi \cdot 91 \cdot 10^{-3} \cdot \left( \frac{14 \cdot 10^{-3} \cdot 15.5 \cdot 10^{-3}}{2} \right) \cos 0.14 = 3.1 \cdot 10^{-5} \text{ m}^3$$

$$K_{T2} = \frac{14 \cdot 10^{-3} \cdot (15.5 \cdot 10^{-3})^3}{12 \cdot 0.2377} = 1.8277 \cdot 10^{-8} \text{ m}^3$$
L_2 = Length of screw cannel, m:

\[ L_2 = \sqrt{(16 \times 10^{-3})^2 + \pi(91 \times 10^{-3}) - (15.5 \times 10^{-3})}^2 = 0.2377 \text{m} \]

B = Width of screw cannel, m.

The pressure made by extruder, Pa:

\[ \Delta P = \frac{1.03 \times 10^6 \times 1.2 \times 3.1 \times 10^{-5}}{(8.209 \times 10^{-9} + 1.8277 \times 10^{-8})} = 1.447 \times 10^9 \text{Pa} \]

Flow rate of the orifice, m^3/sec:

\[ Q_f = \left( \frac{8.209 \times 10^{-9}}{1.03 \times 10^6} \right) \times 1.447 \times 10^9 = 1.153 \times 10^{-5} \text{m}^3/\text{sec} \]

Flow rate of the screw shaft, m^3/sec:

\[ Q_T = 3.1 \times 10^{-5} \times 1.2 = \frac{1.8277 \times 10^{-8}}{1.03 \times 10^6} \times 1.447 \times 10^9 = 1.153 \times 10^{-5} \text{m}^3/\text{sec} \]

Extruder productivity, m^3/sec:

\[ Q_{ex} = \frac{3.1 \times 10^{-5} \times 8.209 \times 10^{-9}}{(1.8277 \times 10^{-8} + 8.209 \times 10^{-9})} \times 1.2 = 1.153 \times 10^{-5} \text{m}^3/\text{sec} \]

The pressure made by extruder, Pa; (for orifice with ring shaping hole):

\[ \Delta P = \frac{1.03 \times 10^6 \times 1.2 \times 3.1 \times 10^{-5}}{(1.8277 \times 10^{-8} + 1.652 \times 10^{-8})} = 1.10 \times 10^9 \text{Pa} \]

Flow rate of the orifice, m^3/sec:

\[ Q_f = \left( \frac{1.652 \times 10^{-8}}{1.03 \times 10^6} \right) \times 1.10 \times 10^9 = 1.76 \times 10^{-5} \text{m}^3/\text{sec} \]

Flow rate of the screw shaft, m^3/sec:

\[ Q_T = 3.1 \times 10^{-5} \times 1.2 = \frac{1.8277 \times 10^{-8}}{1.03 \times 10^6} \times 1.10 \times 10^9 = 1.768 \times 10^{-5} \text{m}^3/\text{sec} \]

Extruder productivity, m^3/sec:

\[ Q_{ex} = \frac{3.1 \times 10^{-5} \times 1.652 \times 10^{-8}}{(1.8277 \times 10^{-8} + 1.652 \times 10^{-8})} \times 1.2 = 1.766 \times 10^{-5} \text{m}^3/\text{sec} \]
4.1.2 The results of extruder design calculations using MATLAB

- The code of extruder design calculations wrote in m-file as shows in Figures 4.1 (a, b).

![Figure 4.1 (a) The code of extruder design calculations in m-file](image1)

![Figure 4.1 (b) (Continued)](image2)
• The results of extruder design calculations in command window when program was running as shows in Figures 4.2 (a, b).

Figure 4.2 (a) The results of extruder design calculations in command window

Figure 4.2(b) (Continued)
4.1.3 The results of extruder design calculations using Visual Basic:

As shown in figure (4.3) Extruder design calculation form has been subdivided into a number of frames. The frame input data used as input frames. Other frames is the Results Frame. Each form contains three main buttons: Calculate, Clear, and Cancel.

**Calculate**: This button is to carry out the design once the input information is complete.

**Clear**: This button is to clear all data; a fresh calculation can then be carried out.

**Cancel**: This button will return the program to the main form.

![Extruder design calculations form](image)

**Figure 4.3** Extruder design calculations form
The results of extruder design calculations form when selecting a ring shape orifice (Ring's hole) as shown in Figure 4.4.

Figure 4.4 The results of extruder design calculations form when selecting a ring shape orifice (Ring's hole)
The results of extruder design calculations form when selecting a conic shape orifice (Cone hole) as shown in Figure 4.5.
4.2.1 Manual design calculations of milk separator:

Sizes of fatty balls:
\[ d = \frac{0.01}{0.04} + 0.5 = 0.75 \text{ m} \]

Pressure of the outlet milk from separator (p), Pa
\[ = 6.62 \times 10^{-4} \text{ Pa} \]

Cream separator productivity (\( \Pi \)) l/h
\[
\Pi = \frac{10^{-6} \times 0.2 \times \pi \times 500^2 \times 130 \times 1 \times (0.18^3 - 0.06^3) \times 0.75^2 \times (1000 - 960)}{4 \times 0.6 \times 10^{-3}} = 1740.6 \text{ l/h}
\]

Continuous operation time between discharges (\( \tau \)),
\[
\tau = \frac{0.1 \times 4800}{1740.6 \times 0.3} = 0.919223 \text{ sec}
\]

The critical rotational frequency of the separator column (\( W_{KP} \)), s\(^{-1}\)
Is the speed at which the column crashes.
\[ = 0.0192 \text{ s}^{-1} \]

k – The force that deforms the column on one meter for the tight-fitting shaft (without installation), (N / m).
\[
K = \frac{3 \times (2 \times 10^{-11}) \times (1.28 \times 10^{-7})}{0.30^2 \times (0.30 + 0.57)} = 980842.9119 \text{ N / m}
\]

I = 0.05 \times (0.040)^4 = 1.28 \times 10^{-7}

The consume power of milk from the separator at excessive pressure (\( N_1 \)), Kwt.
\[ .Kwt \]

Surface area of cylinder (\( F \)), m\(^2\)
\[
F = \frac{\pi \times (0.18^2 - 0.06^2)}{\cos(45)} + 0.4 \times 10^{-3} \times 0.18 \times 130 = 0.1814 \text{ m}^2
\]

Speed of cylinder rotation, (\( v_g \)), m/sec.
\[
V_g = \frac{\pi \times 500 \times 0.18}{30} = 9.424777961 \text{ m/sec}
\]

The necessary power to resist the friction force of the cylinder with air (\( N_2 \)), Kwt.
\[
N_2 = 1.8 \times 10^{-6} \times 1.23 \times 0.137315028 \times (9.42477901)^3 = 3.3590 \times 10^{-4} \text{ Kwt}
\]

Speed of column rotation (\( V_m \)), m/sec
\[ V_m = \frac{\pi \times 500 \times 0.04}{60} = 1.047197551 \text{ m/sec} \]

The consume power to resist friction in bearings \((N_3)\), Kwt.

\[ N_3 = 10^{-3} \times 0.03 \times 10^9 \times 9.8 \times 1.047197551 = 0.033558492 \text{ Kwt} \]

The power of the electric motor of the separator when working continuously \((N)\), Kwt.

\[ N = \frac{1.2 \times (11.6040 + (3.3590 \times 10^{-4}) + 0.03356)}{0.92} = 15.1789 \text{ Kwt} \]
4.2.2 Design calculations results of milk separator using Matlab

The code of milk separator design calculations wrote in m-file as shows in Figures 4.6 (a, b).

Figure 4.6 (a) The code of milk separator design calculations in m-file

Figure 4.6 (b) Continued
The results of milk separator design calculations in command window when program was running as shows in Figures 4.7 (a, b).

Figure 4.7 (a) The results of milk separator design calculations in command window

Figure 4.7 (b) Continued
4.2.3 Design calculations results of milk separator using Visual Basic:

As shown in Figure (4.8) Milk separator design form has been subdivided into a number of frames. The frames Physical Properties and Separator Dimensions are used as input frames. Other frames is the Results Frame. Each form contains three main buttons: Calculate, Clear, and Cancel.

**Calculate**: This button is to carry out the design once the input information is complete.

**Clear**: This button is to clear all data; a fresh calculation can then be carried out.

**Cancel**: This button will return the program to the main form.
4.3 Evaluation of programing results of design calculations of single screw extruder and milk separator

The following tables show the results of comparison evaluations of design calculations of different single screw extruders and milk separators.

**Table 4-1 Comparison between three design calculations methods of single screw extruder**

<table>
<thead>
<tr>
<th>Sym</th>
<th>Manual Calculations</th>
<th>MatLab Calculations</th>
<th>Visual Basic Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cone Die</td>
<td>Ring Die</td>
<td>Cone Die</td>
</tr>
<tr>
<td><strong>Kr</strong></td>
<td>8.209*10^-9</td>
<td>1.652*10^-8</td>
<td>-</td>
</tr>
<tr>
<td><strong>KT1</strong></td>
<td>3.1*10^-3</td>
<td>3.0701e-005</td>
<td>3.07010737463949E-05</td>
</tr>
<tr>
<td><strong>KT2</strong></td>
<td>1.8277*10^-8</td>
<td>1.8306e-008</td>
<td>1.82843031776056E-08</td>
</tr>
<tr>
<td><strong>ΔP</strong></td>
<td>1.447*10^9</td>
<td>1.10*10^9</td>
<td>1.4314e+009</td>
</tr>
<tr>
<td><strong>Q r</strong></td>
<td>1.153*10^-5</td>
<td>1.76 *10^-5</td>
<td>1.1402e-005</td>
</tr>
<tr>
<td><strong>Q t</strong></td>
<td>1.153*10^-5</td>
<td>1.768 *10^-5</td>
<td>1.1402e-005</td>
</tr>
<tr>
<td><strong>Q Ex</strong></td>
<td>1.153*10^-5</td>
<td>1.766*10^-5</td>
<td>1.1402e-005</td>
</tr>
</tbody>
</table>
Table 4-2 Results of computer programs evaluation of design calculations of single screw extruder

<table>
<thead>
<tr>
<th>Symbol</th>
<th>MatLab</th>
<th>Visual Basic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cone Orifice</td>
<td></td>
</tr>
<tr>
<td>Kf</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>KT1</td>
<td>2.2862e-005</td>
<td>2.28607477658757E-05</td>
</tr>
<tr>
<td>KT2</td>
<td>9.6049e-009</td>
<td>9.59728147796985E-09</td>
</tr>
<tr>
<td>ΔP</td>
<td>1.9879e+009</td>
<td>1.2066e+009</td>
</tr>
<tr>
<td>Qf</td>
<td>1.1183e-005</td>
<td>1.8469e-005</td>
</tr>
<tr>
<td>QT</td>
<td>1.1183e-005</td>
<td>1.8469e-005</td>
</tr>
<tr>
<td>QEx</td>
<td>1.1183e-005</td>
<td>1.8469e-005</td>
</tr>
</tbody>
</table>

Table 4-3 Comparison of the results between two different milk separators design calculations

<table>
<thead>
<tr>
<th>Symbol (Unit)</th>
<th>Matlab Program</th>
<th>Visual Program</th>
<th>Basic</th>
<th>Matlab Program</th>
<th>Visual Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Π (l/h)</td>
<td>1.7406e+003</td>
<td>1740.58857873015</td>
<td>1.8457e+003</td>
<td>1845.67523138913</td>
<td></td>
</tr>
<tr>
<td>WKP (s⁻¹)</td>
<td>0.0192</td>
<td>0.0191846504830374</td>
<td>0.0227</td>
<td>0.0227246299424293</td>
<td></td>
</tr>
<tr>
<td>P (pa)</td>
<td>6.6280e-004</td>
<td>0.00066280500207201</td>
<td>5.9071e-004</td>
<td>0.00059070500207201</td>
<td></td>
</tr>
<tr>
<td>τ (sec)</td>
<td>0.9192</td>
<td>0.919229288041912</td>
<td>0.8669</td>
<td>0.866891407973099</td>
<td></td>
</tr>
<tr>
<td>N (KWt)</td>
<td>14.700</td>
<td>14.7003805210373</td>
<td>15.5932</td>
<td>15.5932113325649</td>
<td></td>
</tr>
</tbody>
</table>
4.4 Discussions

This study was carried out to use computer for conducting the complex design calculations of some food processing equipment, namely a single screw extruder and a milk separator. Calculations data and engineering equations were collected from special literature. After that manual traditional methods of calculations were carried out to get reliable results first. Then *MatLab* and *Visual Basic* programs were used to generate these calculations (Figures 4.2, 4.4, 4.5, 4.7, 4.9). The calculations results were shown to be satisfactory and similar to those results obtained by (Antipov *et al.*, 2001; Panfilov and Urakov, 1999). Comparison study was carried out to determine the possibility of the obtained software methods to generate design calculations for others, with different data, food processing equipment. The results of the comparison study were confirmed that the computer programs used in this study had a powerful software development system for creating applications specially in Food Engineering Fields (See tables 4-1, 4-2, 4-3).
Chapter Five

5. Conclusions and Recommendations

5.1 Conclusions

The results of this study show that the using of computerized software programs for conducting the design calculations of food processing equipment had several advantages compared with those obtained using manual and traditional methods. They are generally acceptable and similar to those results recorded by Panfilov and Urakov, 1999). Using computer applications in food processing engineering calculations lead to accuracy in the results. They are easy to use and save time and effort.

5.2 Recommendations

It is recommended that:

- More design calculations of other food processing equipment should be added to the proposed program in this study, in order to develop an integrated programming package for engineering and design calculations of all food processing equipment in a more comprehensive manner similar to the programmed packages used, for example, in chemical engineering fields.

- Other engineering calculations in food analysis and processes should be carried out using the same methods, to obtain the all necessary results in the field of food engineering and technology in order to computerize all complex calculations.
References:


82


Appendices

A. Calculation design of extruder using matlab

\[
\begin{align*}
\pi &= 3.14; \\
\mu &= 1.03 \times 10^6; \\
R &= \text{input}'(\text{Enter value of } R); (r = \text{input}') (\text{Enter value of } r); (h = \text{R-r}); \\
L_1 &= \text{input}'(\text{Enter value of } L_1); (D = 2R-h); \\
n &= \text{input}'(\text{Enter value of } n); (w = \text{input}') (\text{Enter value of } w); \\
\text{if } n > 1; \\
k_f &= \frac{(3\pi R^3 r^3)(R-r)}{(8L_1)((R^3)-(r^3)); ((D = 2R-h)); \\
\text{else} \\
k_f &= ((\pi D)+h)((h^3)/(12L_1); (end; \\
disp') k_f; (DK = \text{input}') (\text{Enter value of } DK); (B = \text{input}') (\text{Enter value of } B); (\text{THETA} = \text{input}') (\text{Enter value of } \text{THETA}); (X = \cos((3.14*\text{THETA})/180); (H = \text{input}') (\text{Enter value of } H); (S = \text{input}') (\text{Enter value of } S); (KT_1 = \pi * D * (B/2) * X \\
L_2 &= (\sqrt{(S^2+(\pi*(D-K-H))^2)}; (KT_2 = (1/12) * (B*H^3/L_2; (DELP = (KT_1/(KT_2+k_f)) * \mu * w \\
Q_f &= (k_f/\mu) * D E L P \\
Q_T &= (K T_1*w-K T_2/\mu*D E L P (Q E x = (K T_1*k_f)/(K T_2+k_f) * w)
\end{align*}
\]

B. Calculation design of milk separator using matlab

\[
\begin{align*}
\pi &= 3.14; \\
\text{Me} &= 0.95; \\
\text{Fe} &= 0.92; \\
g &= 9.8; \\
E &= 2*10^11; \\
\text{beta} &= 0.2; \\
\text{alfa} &= 45; \\
\text{denair} &= 1.23; \\
m &= \text{input}'(\text{Enter value of } m); (d = (m/0.04)+0.5 \\
\text{Dmax} &= \text{input}'(\text{Enter value of } \text{Dmax}); (w = \text{input}') (\text{Enter value of } w); (Z = \text{input}') (\text{Enter value of } Z); (Ro = \text{input}') (\text{Enter value of } \text{Ro}); (R_i = \text{input}') (\text{Enter value of } R_i)
\end{align*}
\]
C. Calculation design of extruder using Visual Basic

PublicClassExtruder

Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
  Dim r As Double
  Dim Rad As Double
  Dim W As Double
  Dim D As Double
  'Code to calculate Dimension coefficient of the shaping organ (Kf)
  r = Val(Textr.Text)
  Rad = Val(TextRad.Text)
  W = Rad - r
  D = 2 * Rad - W
  Dim pi As Single
  Dim l1 As Single
  l1 = Val(TextL1.Text)
  pi = 3.14
  Dim Anskf As Double
  'code to Choose The shape of orifice hole
  If RadioButton2.Checked = True Then
    Anskf = Val((pi * D) + W) * W ^ 3 / (12 * l1)
    Textkf.Text = Anskf
  Else
    If RadioButton1.Checked = True Then
      Anskf = Val(3 * pi * Rad ^ 3 * r ^ 3 * (Rad - r) / (8 * l1 * (Rad ^ 3 - r ^ 3)))
    End If
  End If
  Textkf.Text = Anskf
End If
Dim L2 As Double
Dim S As Double
Dim DK As Double
Dim HI As Double

S = Val(TextS.Text)
DK = Val(TextDK.Text)
HI = Val(TextHI.Text)
L2 = Val(Math.Sqrt(S ^ 2 + (pi * (DK - HI)) ^ 2))

Dim B As Double
B = Val(TextB.Text)

Dim thita As Double
' code to convert unit of angle
If ComboBox1.Text = "dig" Then
    thita = Val(TextThita.Text * 0.0174533)
Else
    thita = Val(TextThita.Text)
EndIf

Dim kH1 As Double
kH1 = Val(pi * DK * ((B * HI) / 2) * Math.Cos(thita))
TextKH1.Text = kH1

Dim kH2 As Double
kH2 = Val(B * HI ^ 3 / (12 * L2))
Textkh2.Text = kH2

Dim deltaP As Double
Dim µ As Double
µ = Val(Textvisco.Text)
Dim ω As Double
ω = Val(Textspeed.Text)
deltaP = Val((µ * kH1 * ω)) / (kH2 + Anskf)
TextDELTAP.Text = deltaP

Dim Qf As Double
Qf = Val((Anskf / µ) * deltaP)
TextQF.Text = QF

Dim QT As Double
QT = Val(kH1 * ω - kH2 / µ * deltaP)
TextQT.Text = QT

Dim Qex As Double
Qex = Val((kH1 * Anskf) / ((kH2 + Anskf)) * ω)

TextQex.Text = Qex

EndSub

Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button2.Click
' Code to clear
Textkf.Clear()
TextKH1.Clear()
Textkh2.Clear()
TextDELTAP.Clear()
TextQex.Clear()
TextQF.Clear()
TextQT.Clear()

EndSub
Private Sub Button3_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button3.Click
' Code to exit from program
Application.Exit()
End Sub
End Class

D. Calculation design of milk separator using Visual Basic

Public Class Milk_separator

Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
Dim d As Double
Dim m As Double
m = Val(Textm.Text)
d = Val((m / 0.04) + 0.5)
Dim Ro As Double
    Ro = Val(TextRo.Text)
Dim rk As Single
rk = Val(textrk.text)
Dim pcmax As Single
pcmax = Val(Textpcmax.Text)
Dim P As Double
    P = Val((pcmax / 50000) * (Ro ^ 2 - rk ^ 2))
TextP.Text = P
Dim pi As Double
    pi = 3.14
Dim β As Single
    β = 0.2
Dim w As Double
    w = Val(Textw.Text)
Dim Z As Double
    Z = Val(TextZ.Text)
Dim α As Single
    α = Val(Textalfa.Text)
Dim Ri As Double
    Ri = Val(TextRi.Text)
Dim pm As Double
    pm = Val(Textpm.Text)
Dim pc As Double
    pc = Val(Textpc.Text)
Dim µmilk As Double
    µmilk = Val(Textµmilk.Text)
Dim Π As Double
    Π = Val((10 ^ -6 * pi * β * w ^ 2 * Z * Math.Tan(α) * (Ro ^ 3 - Ri ^ 3) * d ^ 2 * (pc - pm)) / (4 * µmilk))
TextΠ.Text = Π
Dim V As Double
    V = Val(TextV.Text)
a = Val(Texta.Text)
Dim τ As Double
    τ = Val((0.1 * V) / (Π * a))
Texttao.Text = τ
Dim dc As Single
    dc = Val(Textdc.Text)
Dim I As Double
    I = 0.05 * dc ^ 4
Dim C As Double
    C = Val(TextC.Text)
Dim L As Double
    L = Val(TextL.Text)
Dim pe As Double
    pe = 2 * 10 ^ 11
Dim K As Double
    K = Val((3 * pe * I) / (C ^ 2 * (C + L)))
Dim mg As Integer
    mg = Val(Textmg.Text)
Dim Wkp As Double
    Wkp = Val(L / ((L - C) * Math.Sqrt(K / mg)))
TextWkp.Text = Wkp
Dim ηd As Double
    ηd = 0.92
Dim N1 As Double
    N1 = Val(((Π * 2) / (0.3 * 1000))
    TextN1.Text = N1
Dim vg As Double
    vg = Val((pi * w * Ro) / 30)
Dim F As Double
    F = Val(((Ro ^ 2 - Ri ^ 2) / Math.Cos(α)) + 0.4 * 10 ^ -3 * Ro * Z)
Dim pa As Double
    pa = Val(Textpa.Text)
Dim N2 As Double
    N2 = Val(1.8 * 10 ^ -6 * F * pa * vg ^ 3)
    TextN2.Text = N2
Dim GM As Integer
    GM = Val(TextGM.Text)
Dim Fr As Single
    Fr = 0.03
Dim ηm As Double
    ηm = 0.95
Dim g As Single
    g = 9.8
Dim vm As Double
    vm = Val((pi * w * dc) / 60)
Dim N3 As Double
    N3 = Val(10 ^ -3 * Fr * GM * g * vm)
    TextN3.Text = N3
Dim N As Double
    N = Val((1.2 * (N1 + N2 + N3)) / ηm)
TextN.Text = N
EndSub

Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button2.Click
    Texttotal.Clear()
    TextN1.Clear()
    TextN2.Clear()
    TextN3.Clear()
    TextFr.Clear()
    TextWkp.Clear()
    TextN.Clear()
    TextGm.Clear()
End Sub

Private Sub Button3_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button3.Click
    Application.Exit()
End Sub

End Class