

Preparation of Soaps from Animal Fat

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Master's thesis
2024



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Faculty of Technology

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Department of Polymer Engineering

Academic year: 2023/2024

ASSIGNMENT OF DIPLOMA THESIS

(project, art work, art performance)

Name and surname:	Dennis Ugochukwu Uwaezuoke
Personal number:	T22666
Study programme:	N0722A130002 Polymer Engineering
Type of Study:	Full-time
Work topic:	Preparation of Soaps from Animal Fat

Theses guidelines

1. In the theoretical part of the thesis describe the contemporary state of the art with regard to the studied topic.
2. In the practical part, propose the procedure of processing of animal fat into toilet soaps.
3. Study the influence of selected processing parameters on the yield and properties of prepared soaps.
4. Work out the results using the statistical software into tables, graphs, analyse them and compare/contrast them with the results of similar studies.
5. Evaluate the importance of the results for the practice and for further research.

Form processing of diploma thesis: **printed/electronic**
Language of elaboration: **English**

Recommended resources:

Spitz, L. *Soap Manufacturing Technology*. Amsterdam: Academic Press, 2006.
EIRI Board. *Modern Technology of Acid Slurry, Surfactants, Soap and Detergents with Formulae*. New Delhi: Engineers India Research Institute, 2020.
Ockerman, H.W.; Hansen C.I. *Animal By-product Processing and Utilization*, 1st ed.; CRC Press: London, Great Britain, 2000.
Sharma, H.; Giriprasad, R.; Goswami, M. Animal fat-Processing and Its Quality Control. *J. Food Process. Technol.* 2013, 4, 8.

Supervisors of diploma thesis: **prof. Ing. Pavel Mokrejš, Ph.D.**
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Date of assignment of diploma thesis: **January 2, 2024**

Submission deadline of diploma thesis: **May 10, 2024**

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ABSTRAKT

Výroba mýdla ze zvířecího tuku představuje udržitelný a účinný způsob přeměny přírodních zdrojů na cenné výrobky pro domácnost. Teoretická část diplomové práce se zabývá přehledem tuků a mastných kyselin, jejich fyzikálními a chemickými vlastnostmi, zpracování živočišných a rostlinných tuků a olejů a jejich využitím. Praktická část se zabývá přípravou mýdel ze zvěřinového tuku (daněk). Postup práce spočívá ve zmýdelnění živočišného tuku alkalickým postupem; v tomto případě byl použit hydroxid draselný. Byly testovány 3 procesní faktory pro získání různých vzorků mýdel: teplota, množství KOH a množství NaCl použité k vysolení metodou faktorového schématu. Byla vyhodnocena výtěžnost mýdla a provedena série fyzikálně-chemických analýzy mýdel ke stanovení jejich kvality – pH, celková alkalita, pěnivost, stabilita pěny, celkový obsah tuku a vlhkost; dále tvrdost mýdla penetračním testem, V závěru práce jsou uvedeny optimální podmínky procesu přípravy mýdla z tuku daňka.

Klíčová slova: dančí tuk, vedlejší produkty, mastné kyseliny, mýdlo, zmýdelňování, procesní podmínky, testování mýdel, kosmetika, potravinářství, plánované experimenty.

ABSTRACT

Producing soap from animal fat offers a sustainable and efficient means of transforming natural resources into valuable household commodities. The theoretical aspect of the master thesis presents an overview of fats and fatty acids and their physical and chemical properties, the processing of animal fats and oils, as well as other utilization of animal fats. The practical aspect deals with providing a detailed process of preparing soap from venison fats, specifically from fallow deer fat. The methodology typically involves saponifying animal fats with alkali substances. In this case, potassium hydroxide was used. Three processing conditions were tested: temperature, amount of KOH, and amount of NaCl used for salting out using the factorial scheme method to obtain different samples. This method enables the production of different soap samples with varying processing conditions. The soap yield and physicochemical analysis, such as pH, total soap alkalinity, foaming capacity, foam stability, penetration (soap hardness), total fatty matter, and moisture content, were evaluated to determine the quality of soap and set up an optimal condition for the process.

Keywords: deer fat, by-products, fatty acids, soap, saponification, processing conditions, soap testing, cosmetics, food industry, design of experiments.

ACKNOWLEDGEMENTS

I am profoundly grateful to Almighty God for granting me the strength, knowledge, peace of mind, good health, and opportunity to undertake and successfully complete this study.

I extend my deepest thanks to my supervisor Prof. Ing Pavlo Mokrejš, Ph.D., for his guidance, unwavering support, and insightful feedback throughout this thesis journey. His expertise and constant encouragement have significantly shaped this thesis and improved its quality.

I express my heartfelt appreciation to Mrs. Ing. Tereza Novotná, Ph.D. for consultations for the practical part of the thesis, as well as Mrs. Petra Elšíková for her assistance with the work in the laboratory.

To my parents Mr. and Mrs. Cyril Uwaezuoke, I am grateful for your resilience and unwavering support, which has been a source of inspiration. Your belief in my potential has been a motivating factor to pursue my dreams without doubt.

I also want to thank my brother Mr. Cyracus Uwaezuoke for his support and encouragement throughout this study as well as my friends especially Miss Emmanuella Tetteh for their support in making the project a success.

Lastly, my sincere appreciation goes to my lovely wife Mrs. Janet Michael for her boundless love, encouragement, and understanding, which contributed to the success of this project.

I hereby declare that the print version of my Master's thesis and the electronic version of my thesis deposited in the IS/STAG system are identical.

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INTRODUCTION

Soap is a common cleansing agent. K.J Betsy described soap as sodium or potassium salts of various naturally occurring fats produced by saponification or basic hydrolysis reaction of fat or oil. The fatty acids such as stearic, palmitic, myristic, lauric and oleic acids are major contributors to the lathering and washing properties of soap. The purpose of producing soap may include washing, bathing, medication etc. [1]

The cleansing action of soap is due to the negative ions on the hydrocarbon chain attached to the carboxylic group of fatty acids. In the cleansing action of soap on oil and grease, the hydrocarbon chains have affinity for oil and grease while the carboxylic group is to water. This is the main reason why soap is mostly used with water for cleansing purposes [2]. However, soap quality can be characterized as the function of the strength and purity of alkali, the kind of oil used, completeness of saponification and the age of soap.[3]

Fats belong to the wider lipid family. Lipids are a relatively heterogeneous group of substances. A common property of lipids is that they repel each other with water. The basis of every fat is the trihydric alcohol glycerol and on it three ester-linked acids, called fatty acids. Fatty acids differ in chain length, degree of unsaturation, position, and orientation of the double bond in the hydrocarbon chain. Fatty acids, which have an even number of carbons in the molecule, are mainly found in nature. Small amounts of fatty acids with an odd number of carbon atoms.

In my diploma thesis, I deal with purification of animal raw fat (Deer) which was used in preparing soap samples, which was achieved by changing the processing conditions such as amount of KOH, amount of NaCl for salting and the saponification temperature to analyze the soap properties as well as defining an optimal production condition.

I. THEORETICAL PART

1. LIPIDS

Lipids are important components of food and in human nutrition they form one of the main nutrients necessary for the health and development of the organism. There is no precise definition available for the term lipid, but it usually includes a broad category of compounds that share some common properties and similarities in composition. Classification of lipid structures is possible based on physical properties at room temperature when we can divide them into liquid oils and solid fats. Another division is according to their polarity into polar and neutral or according to their structure into simple and complex. Neutral lipids include fatty acids, alcohols, glycerides, and sterols, while polar lipids include glycerophospholipids and glyceroglycolipids. The division into classes according to polarity is rather arbitrary, since some short-chain fatty acids are very polar. Therefore, structure-based classification is more appropriate. Simple lipids composed of fatty acids and alcohol components include acylglycerols, etheracylglycerols, sterols and their esters, and wax esters. Simple lipids can be hydrolyzed into two different components, usually an alcohol and an acid. Complex lipids glycerophospholipids (phospholipids), glyceroglycolipids (glycolipids) and sphingolipids. These structures yield three or more different compounds on hydrolysis. Lipids are among the main components of food of plant and animal origin. [4][5]

1.1 Fats

Fats belong to the wider lipid family. The chemical and physical properties of fats and oils are determined by the fatty acids they contain and their position within the triacylglycerol molecule. Chemically, all fats and oils are esters of glycerin and fatty acids. Fats and oils are commonly called triglycerides because the glyceride molecule has three hydroxyl groups to which fatty acids can be attached. All triglycerides have the same glycerin unit, meaning that the fatty acids contribute to different properties. [5][6]

1.2 Fatty acids

Fats or lipids are composed of many chemical compounds, including monoglycerides, diglycerides, triglycerides, phosphatides, cerebrosides, sterols, terpenes, fatty alcohols, and fatty acids. Fatty acids form the main component of phospholipids, triglycerides, diglycerides, monoglycerides and sterol esters. Fatty acids are composed of elements such as carbon, hydrogen, and oxygen arranged as a linear carbon chain of varying length with a carboxyl group

at one end. Fatty acids can be saturated (no double bond), monounsaturated (one double bond), or polyunsaturated (more than one double bond) and are essentially for energy, metabolic, and structural activities.[7] [8]

- **Saturated fatty acids**

Saturated fatty acids are a common component of natural lipids, they normally contain 4 to 38 carbon atoms (but there are higher fatty acids with about 60 carbon atoms). They usually have a straight, unbranched chain, most often with an even number of carbon atoms. In most natural lipids, they make up 10-40% of the total fatty acids. According to the number of carbon atoms (chain length), saturated fatty acids are distinguished: lower fatty acids (C4 and C6), medium-chain fatty acids (C8-C12), long-chain fatty acids (C14- C18), very long chain (C20- C26) and ultra-long chain (C28-C38). The most crucial ones are listed in Tab. 1. [5][9]

Saturated fatty acids are typically found in high content (mainly palmitic and stearic acid) in the fat of farm animals, mainly pigs and ruminants. In the depot fat of commercial birds, the content of saturated fatty acids is lower. Fatty acids with a shorter chain, such as butyric acid and a group of acids with 6-10 carbons in the molecule, are typical for milk fats. Palm seed oils are high in lauric acid, accompanied by myristic acid and acids with 6-10 carbons. In coconut oil, free fatty acids contain less saturated fatty acids than bound fatty acids. [9]

Fatty acid	Number of atoms carbon	Trivial name	Fatty acid	number of atoms carbon	Trivial name
Butanoic	4	Butyric	Eicosanoic	20	Arachidic
Hexanoic	6	Caproic	Docosanoic	22	Behenic
Octanoic	8	Caprylic	Tetracosanoic	24	Lignoceric
Decanoic	10	Capric	Hexacosanoic	26	Cerotic
Dodecanoic	12	Lauric	Octacosanoic	28	Montanic
Tetradecanoic	14	Myristic	Triacosanoic	30	Melissic
Hexadecanoic	16	Palmitic	Dotriacontanoic	32	Lacceric
Octadecanoic	18	Stearic	Tetratriacontanoic	34	Gheddic

Table 1: saturated fatty acids found in lipids.

- **Unsaturated fatty acids with one double bond**

Unsaturated fatty acids with one double bond are known as monoenes. They differ from each other in the number of carbon atoms, the position of the double bond and its spatial configuration. Many monoenoic fatty acids have trivial names that are commonly used. A few less common monoene fatty acids are found in larger quantities only in the most important sources of lipids, they are usually only present in traces in food. The most important monoenoic fatty acids are listed in the Table below. [5][9]

Fatty acid	Number of atoms carbon	Position double bonds	Isomer	A trivial name
Decenoic	10	4	<i>cis</i>	Obtusillic
Decenoic	10	9	<i>cis</i>	Caproleic
Dodecenoic	12	3	<i>cis</i>	Linderic
Dodecenoic	12	9	<i>cis</i>	Lauroleic
Tetradecenoic	14	4	<i>cis</i>	Tsuzuic
Tetradecenoic	14	9	<i>cis</i>	Myristoleic
Hexadecenoic	16	9	<i>cis</i>	Palmitoleic
Hexadecenoic	16	9	<i>trans</i>	Palmitelaidic
Octadecenoic	18	6	<i>cis</i>	Petroselinic
Octadecenoic	18	6	<i>trans</i>	Petroselaidic
Octadecenoic	18	9	<i>cis</i>	Oleic
Octadecenoic	18	9	<i>trans</i>	Elaidic
Octadecenoic	18	11	<i>trans</i>	Vaccenic
Eicosenoic	20	9	<i>cis</i>	Gadoleic
Eicosenoic	20	11	<i>cis</i>	Gondoic
Docosenoic	22	11	<i>cis</i>	Cetoleic
Docosenoic	22	11	<i>trans</i>	Cetelaidic
Docosenoic	22	13	<i>cis</i>	Erucic
Docosenoic	22	13	<i>trans</i>	Brassidic
Tetracosenoic	24	15	<i>cis</i>	Nervonic
Hexacosenoic	26	17	<i>cis</i>	Ximenic
Triacosenoic	30	21	<i>cis</i>	Lumequeic

Table 2: Main monoenoic fatty acids found in lipids.[5][9]

- **Unsaturated fatty acids with two or more double bonds**

Fatty acids with two double bonds (diene) are very important in nutrition. Although theoretically there could be far more of them than monoenoic fatty acids, only a few are found in significant amounts in natural lipids. Also, the number of naturally occurring fatty acids with

three double bonds is considerably smaller, than would correspond to the possibilities of isomerism. Fatty acids with four to six double bonds in the molecule are also relatively rare.[5][9]

Animal fats and vegetable oils mostly contain unsaturated straight chain fatty acids with 10-36 carbon atoms. The most common fatty acids are monoenoic and polyenoic fatty acids with 16-18 carbon atoms. The unsaturated fatty acids content of fats and oils ranges widely, it accounts up to 90% of the total fatty acids in rapeseed oil to less than 10% in coconut oil. In comparison, animal fat which occur in a much smaller concentration range usually between 50-70%, excluding fish oil because it contains fatty acids with 20-22 carbon atoms and 4-6 double bonds. The fat of freshwater fish differs in composition from the fatty acids in the fat of marine fish. Fish do not synthesize these fats themselves but receive them from the food they eat (algae, crustaceans, and plankton). Even aquatic mammals such as whales, which feed on crustaceans and plankton, have fat with a similar fatty acid composition as fish.[9]

Fatty acid	Number of atoms carbon	Double position bonds	Configuration double bonds	Trivial name
per diem				
octadecadiene	18	9,12	<i>cis, cis</i>	linoleic
octadecadiene	18	9,12	<i>trans, trans</i>	linoleic
triene				
octadecatriene	18	9, 12, 15	<i>all-cis</i>	α-linolenic
octadecatriene	18	6,9,12	<i>all-cis</i>	γ-linolenic
tetraenes				
eicosatetraene	20	5,8,11,14	<i>all-cis</i>	arachidonic
docosatetraene	22	7,10,13,16	<i>all-cis</i>	adrenal
pentaenes				
eicosapentaenoic	20	5,8,11,14,17	<i>all-cis</i>	EPA
docosapentaenoic	22	7,10,13,16,19	<i>all-cis</i>	clupanodon
hexane				
docosahexaenoic	22	4,7,10,13,16,19	<i>all-cis</i>	DHA

Table 3: Main important polyenoic fatty acids found in fats [9]

1.3 Physical properties of some fatty acids

- **Melting point**

The melting point of saturated fatty acids are influenced by the number of the carbon atoms in the hydrocarbon chain. Saturated fatty acids with a hydrocarbon chain longer than 10 carbon atoms are solid at room temperature, and those with shorter chains are liquid. As the number of carbon atoms increases, up to twenty carbon atoms, their melting point increases. A further increase in the number of carbon atoms will no longer significantly affect the melting point. Fatty acids with an odd number of carbon atoms melt at a lower temperature than fatty acids with an even number of C atoms, which are one carbon atom leaner. [10]

Fatty acid	Chain	Trivial name	Molecular Mass [g/mol]	Melting point
Butanoic	4	Butyric	88.1	-5.3
Hexanoic	6	Caproic	116.2	-3.2
Octanoic	8	Caprylic	144.2	16.5
Decanoic	10	Capric	172.3	31.6
Dodecanoic	12	Lauric	200.3	44.8
Tetradecanoic	14	Myristic	228.4	54.4
Hexadecanoic	16	Palmitic	256.4	62.9
Octadecanoic	18	Stearic	284.5	70.1
Eicosanoic	20	Arachidic	312.5	76.1
Docosanoic	22	Behenic	340.5	80.0

Table 4: melting point and molecular mass of selected saturated acids [10]

- **Boiling point**

The boiling points of fatty acids are high, so they cannot be distilled at atmospheric pressure without degradation. For unsaturated fatty acids, it increases with the increasing number of carbon atoms, and the presence of double bonds affects it only slightly. [10]

Fatty acid	Chain	Trivial name	Molecular Mass [g/mol]	Boiling point
Butanoic	4	Butyric	88.1	163.5
Hexanoic	6	Caproic	116.2	205
Octanoic	8	Caprylic	144.2	237
Decanoic	10	Capric	172.3	271
Dodecanoic	12	Lauric	200.3	298.9
Tetradecanoic	14	Myristic	228.4	250.5
Hexadecanoic	16	Palmitic	256.4	333
Octadecanoic	18	Stearic	284.5	355

Table 5: Comparison of boiling points of selected fatty acids [10]

1.4 Division of vegetable oils by fatty acid group

- **Oleic acid group**

This group includes vegetable oils obtained from seeds, kernels, and fruits, which contain more than 50%, some even 80% or more oleic acid, a maximum of 30% linoleic acid and no or only a small amount of linolenic acid, or even higher unsaturated fatty acid. The content of saturated acids does not exceed 20%. These are non-drying or very weakly drying durable oils. Therefore, they are mainly used for nutrition as table salad oils or as part of margarine and cooking fats. This group includes olive oil, peanut oil, almond oil and others. [11]

- **Linoleic acid group**

The oils of this most numerous groups have, in addition to a high content of oleic acid, also a large proportion of linoleic acid (30 to 70%). As the degree of oleic acid decreases, the content of linoleic acid increases. They do not contain linolenic acid at all or only in very small amounts. These are semi-drying oils. The most important oils of this group are sunflower, soybean, cotton, and sesame oil. These oils are used in liquid or solidified form in large quantities to produce edible oil and fat. [11]

- **Linolenic acid group**

This group belongs to drying oils, for a vegetable oil to have good drying properties and be

used for coating applications, it must contain a large amount of linoleic acid, or a small amount of linolenic acid and at least 60% linoleic acid. They are mainly utilized in paints production, but also suitable for human nutrition. For example, linseed and hemp oil [11]

- **Palmitic, stearic or myristic acid groups**

Fats and oils of this group are solid or semi-solid at room temperature. They contain 45-50% but also have saturated fatty acids, namely palmitic and stearic acids, the rest being oleic and linoleic acids. They include palm oil, cocoa butter, shea butter etc. [11]

1.5 Distribution of animal fats by fatty acid group

- **Butyric acid group**

Fats from the milk of terrestrial domestic animals belong to this group. It is characteristic of milk fats that they contain, as the only fat, a greater amount of butyric acid and all its homologues with an even number of carbon atoms up to behenic acid, then decenic acid and all its homologues up to octadecanoic acid. Lower fatty acids are relatively abundant in the fatty acids of milk fat. [11]

- **Palmitic and stearic acid group**

Fats of this group, like fats of the palmitic and stearic group of vegetable origin, contain a lot of palmitic and stearic acid, which make up most saturated fatty acids. In addition to these two acids, animal fats contain 35 to 50% oleic acid. Apart from poultry fat, the content of linoleic acid is small, the content of higher unsaturated fatty acids is negligible. This group includes stored animal fats such as pork fat and tallow, rendered fat, poultry fat and others. [11]

1.6 Fat by-products from animal slaughterhouses

Animal fats are rendered tissue fats that can be obtained from a variety of animals. Basically, they are by-products of the meat packing industry, made available because of the preparation of meat either for sale or from the manufacture of meat product.[12]

1.6.1 Types of animal fat

- **Tallow**

it is hard fat rendered from the fatty tissues of cattle that are removed during processing of beef.

There are two types of tallow:

-**Edible tallow:** it is recognized as rendered fat from certain organs of healthy bovine animals. It is also known as dripping.

- **Oleo-stock:** it is high grade tallow that is obtained by low temperature wet rendering of the fresh internal fat from beef carcass. Its light yellow in color, mild pleasant flavor and free fatty acid content is less than 0.2% [1]. Oleo-stock is also known by the synonym *premier jus*. [12]

- **Lard**

It is defined as the fat rendered from clean, sound edible tissues of hogs in good health at the time of slaughter. Its production is limited to certain killing and cutting fats from the hog. Depot fats such as those surrounding the kidney portion are examples of killing fats, since they are removed during the slaughtering operation. Cutting fats are those fats which are obtained when the hog is cut into its various wholesale or retail cuts.[12]

- **Caul fat**

It is the fatty membrane which surrounds internal organs of some animals, such as cow, sheep, and pigs also known as the greater omentum. It is often used as a natural casing. It is also known as *Lace Fat*. [12]

- **Leaf fat**

It is the fat lining the abdomen and kidneys of hog that used to make the lard.[12]

- **Rendered pork fat**

It is the fat other than the lard, rendered from clean, sound carcasses or edible organs from hogs in good health at the time of slaughter, with certain parts of the animal specifically excluded. It includes bacon skins, fleshed skins, cheek meat trimmings, sweet pickle fats and fats obtained from skimming the rendered tanks.[12]

- **Inedible tallow and greases**

These are the main inedible animal fats which are produced in many grades. Inedible tallow and greases produced by meat packing meat industry may contain either hog or beef fat. These are described in terms of their hardness. Fat with titer of 40 or greater than 40 are known as inedible tallow and those with titers less than 40 are called as greases. Titer is the measure of the temperature developed because of the heat of crystallization during cooling of melted fatty acids from the fat.[12]

- **Chicken fat**

It is the fat obtained (usually as a by-product) from chicken rendering and processing. It is high in linoleic acids, the beneficial omega-6 fatty acid. Linoleic acid levels are between 17.8-22.9%. It is used in the production of pet foods and biodiesel. Chicken fat is one of the two types of animal fat referred as *schmaltz*, the other being goose fat.[12]

1.7 Legislative lay-out regarding tackling with fat by-products in EU

The "Meat Products Directive" (77/99/EEC) governs the fat processing sector, while the "Animal By-Products Regulation" (ABPR 1774/2002/EC) regulates the rendering sector.

Both sectors are subject to the principles of Hazard Analysis and Critical Control Points (HACCP) for ensuring food safety. This applies throughout the entire process, from slaughterhouse to processing plant to the destination of the products. The implementation of HACCP systems, combined with movement documentation, ensures full traceability from farm to fork. Moreover, various codes of practice have been developed and adopted by different sectors within the industry to meet both legislative requirements and retail pressures. Currently, EFPRA STG (European Fat Processors and Renderers Association - Scientific and Technical Group) is working on developing codes of practice to international standards, such as the Codex standard, in collaboration with allied industries and potential users like animal feed associations FEFAC and Copac/Cocega.[13]

2. PROCESSING OF ANIMAL FAT

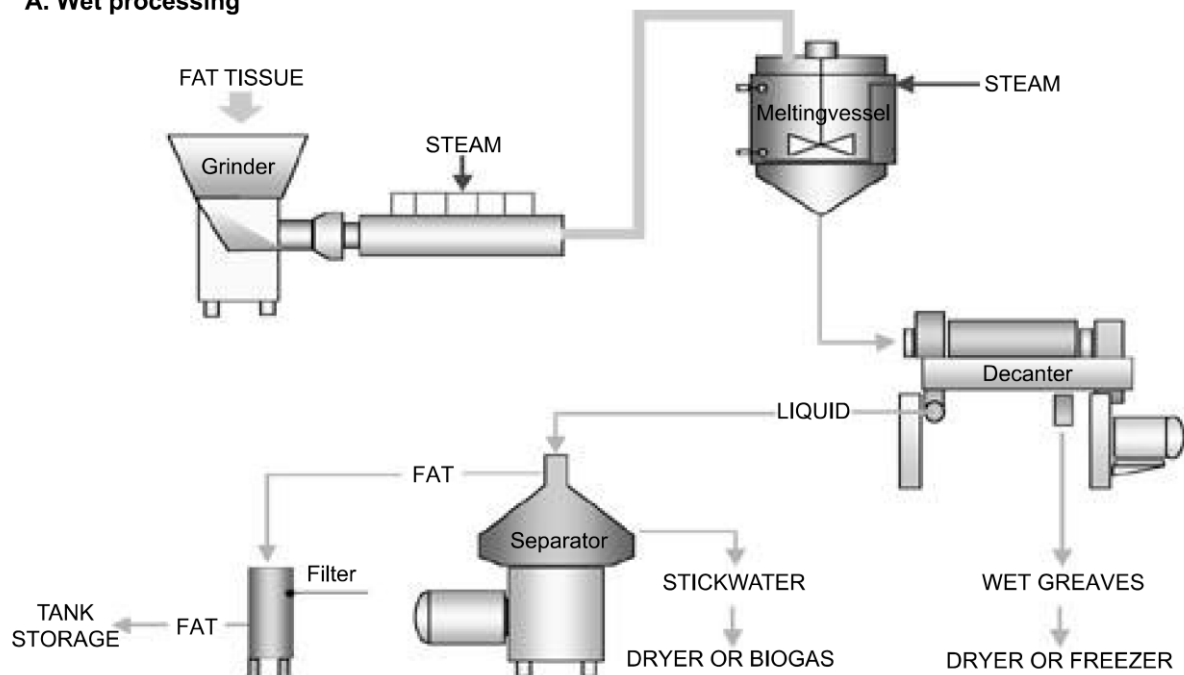
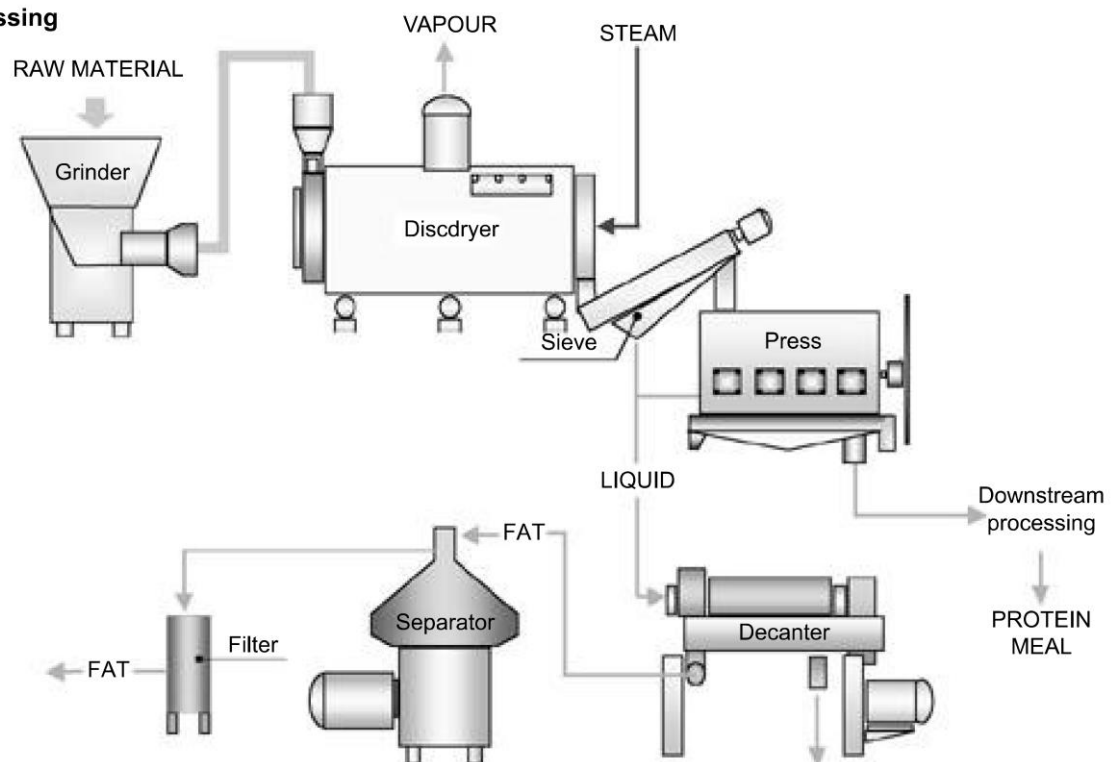
Fats are produced by a variety of processes, generally referred to as rendering. Fatty tissues from both beef and pork are composed of essentially three components, viz. water, protein, and fat. It is the purpose of any rendering system to obtain as complete a separation as feasible of these materials. In most cases, the fatty tissues are cooked, and the fat is released by temperature and cell rupture. In alternative process, the temperature is kept low, and the fat is released principally through mechanical rupture of the cells.[12]

Rendering of fat is the thermal processing operation that breaks down the cellular structures to release triacylglycerols from animal by-products and underutilized fish species. There is two main method of fat rendering namely:

- Wet rendering
- Dry rendering

2.1.1 Wet renderer: This is generally vertical type equipment in which steam comes in direct contact with raw material or charge. The material is cooked at 40psi for 4-8 hrs. After processing, the tankage or slush is allowed to settle for 2 hrs. These greasy or fatty material which floats on top is removed first, followed by water and finally by the tankage with digested meat and bones. The bones are sent to bone digester. This method has an advantage of better fat recovery.[12]

2.1.2 Dry renderer: A dry renderer is made up of horizontal stem jacket with raw material or charge load of 8-10 quintals. Two or three stirrers keep the raw material continuously under motion for uniform heat distribution to avoid charring. The steam remains in the outer jacket and does not come in direct contact with raw material or charge which is cooked at 75psi for 3-4 hrs in its own moisture. There is no loss of nutrients in this. The resultant material called "*cracklings*" is taken out. The cracklings should be gritty, fibrous, and non-slippery. It still contains lot of fat; thus, fat is removed to 5% in order to economize the labour and to increase the keeping quality of material. Removal of fat is done from cracklings inside the centrifugal expeller and fat settling tank.[12]

A. Wet processing**B. Dry processing****Figure 1.** Schematic diagrams of two rendering processes [13]

2.2 Processing of crude Soyabean oil into edible oil

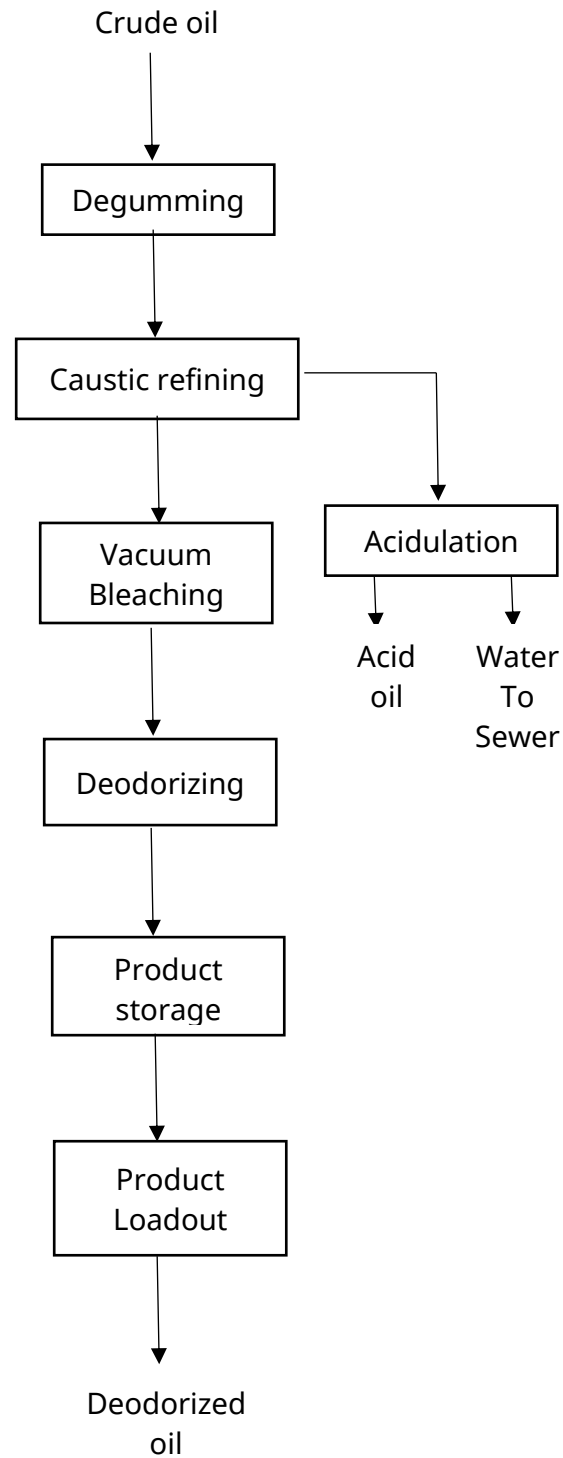


Figure 2 Conventional Refining process [14]

2.2.1 Degumming

Crude soyabean oil is degummed primarily to:

- Produce oil free from settling materials for export.
- Recover phosphatides for processing of soyabean lecithin.
- Remove emulsifying agents like phosphatides and mucilaginous gums which can increase oil loss during alkali refining.

The principal method in the United States involves batch treatment of the oil with 1 to 3% water, based on oil volume. This mixture is then agitated for 30-60 minutes at 70-80°C. The hydrated phosphatides and gums can then be separated from the oil through settling, filtering, or centrifuging. Though this method removed about 90% of the phosphatides, there are some remnants which can be removed using phosphoric acid treatment to remove these non-hydratable phosphatides as well as chlorophyll more effectively before alkali refining. The sludge obtained from degumming soybean oil is a mixture of several phosphatides plus an oil carrier and other ingredients, this mixture after drying is marketed as commercial soybean lecithin which serves as a wetting and emulsifying agent. [14]

2.2.2 Alkali refining

Refining of soybean oil is practiced as a purifying treatment designed to remove free fatty acids, phosphatides and gums, coloring matter, insoluble matter, settlings and miscellaneous "unsaponifiable" materials. The treatment has little effect on the triglycerides of the oil. If crude oil is to be alkali refined it is conditioned with phosphoric acid to facilitate the purifying treatment [14]. Essentially all soybean oil in the United States is refined by the continuous process. An amount of 17-18 ~ Be' caustic, based on the free fatty acid content of the oil plus a 0.10-0.13% excess is proportioned into the crude oil and mixed in a high-shear in-line mixer. The soap-oil mixture is heated to 75-80°C and fed to a pressure or hermetic type centrifuge for separation into light and heavy density phases. Light-phase discharge consists of refined oil containing traces of moisture and soap; the heavy phase is primarily soap, insoluble material, free caustic, phosphatides, and a small quantity of neutral oil. Refined oil is washed with 10-20% by weight of soft water at 90 C. The water washing process removes about 90% of the soap content in the refined oil; the remainder of the soap is removed in the bleaching process. [14]. Soapstock and wash water are combined and treated with sulfuric acid to convert the soap

into crude fatty acids. Most of the acidulated soap stock is used as a high energy ingredient in animal feed. Other byproducts which is obtained during the refining process is sterols.[14]

2.2.3 Bleaching

Bleaching of alkali-refined oils removes entrained soaps and reduces color bodies in the oil; it is more appropriately referred to as adsorption treatment. Although batch atmospheric bleaching is still used to some extent in the United States, batch or continuous vacuum bleaching is generally practiced. The process consists of agitation of the oil with 0.5-1.5% acid activated earth at 90-95°C for 15-30 min at a vacuum of 26-28 in. Hg followed by filtration to give a clean, clear oil.[14]

2.2.4 Deodorization

In the edible oil refinery, deodorization is the last process step used to improve the taste, odor, color and stability of the oil by the removal of undesirable substances. All commercial deodorization, whether in continuous, semicontinuous or batch units, is essentially a steam stripping of the oil for removal of free fatty acid (FFA) and other volatile compounds. During the process, peroxide decomposition products, color bodies and their decomposition products are eliminated and the contents of sterols, sterol esters and tocopherols are reduced. The goal of deodorization is to produce a finished oil that has a bland flavor, a maximum FFA content of 0.05% and a zero-peroxide value. The modern commercial deodorizer is equipped with a pollution control system that consists of three steps: the deodorizer distillate recovery system, closed circuit condensing water system and the vapor scrubbing system. The distillate recovery system removes 80-90% of the distillate from the steam train before it reaches the condenser. The short chain fatty acid fractions pass through the recovery unit and are recovered from the vapor scrubbing system. The deodorizer distillate is a concentrate of tocopherols and sterols and is a valuable source of these materials. [15] [16]

Absolute pressure	1-6mm Hg
Deodorization temperature	210-274°C
Holding time at elevated temperature	3-8hours
Batch type (continuous/ semi continuous)	
Stripping steam: wt% of oil	5-15%
Produce free fatty acid	1-5%
Feed, including steam refining	0.05-6%
Deodorized oil	0.02-0.05

Table 6: Commercial Deodorization conditions [15]

2.3 Utilization of animal fat byproducts

Utilization in food industry

Lard and butter are the primary edible animal fats, which were extracted from fat tissues of pigs and cattle/sheep respectively. Wet extraction techniques yield higher quality products compared to the dry extraction technique, while refined lard can be directly used as edible oil without additional processing. Nowadays enzymatic methods are employed in the extraction of lard from pig fatback which has significantly improved physical and chemical properties compared to traditionally extracted lard. In fast food industry liquid butter products has been developed for the preparation of French fries because less fat is absorbed. Butter and lard are used in margarine and shortening. Some edible lard products are used in sausage or emulsified products.

Utilization for biodiesels

Biodiesel presents a compelling alternative to conventional fossil fuels, derived through chemical processes from renewable sources such as vegetable oils and animal fats. Its adoption offers several advantages over traditional diesel. Compared to standard diesel, biodiesel boasts lower toxicity, facilitating safer handling and storage. Additionally, its rapid decomposition facilitates easier cleanup in case of spills, minimizing environmental damage.

Biodiesel is produced through the transesterification reaction of a fat with a short-chain alcohol in the presence of a catalyst. Different catalysts are available to be used for biodiesel production.

Those most typically used in transesterification reactions are alkalis (sodium hydroxide, sodium methoxide, potassium hydroxide, potassium methoxide, sodium amide, sodium hydride, potassium amide and potassium hydride), acids (sulfuric acid, phosphoric acid, hydrochloric acid, or organic sulfonic acid), heterogeneous catalysts like enzymes (lipases) and complex catalysts like silicates, zirconias, nanocatalysts, etc. A faster reaction rate of animal fats transesterification is obtained using alkali catalysts in comparison to acid catalysts [17,18] which are 4000 times faster [19] as well as less expensive and readily available [20]. Transesterification process converts triacylglycerols to glycerol.

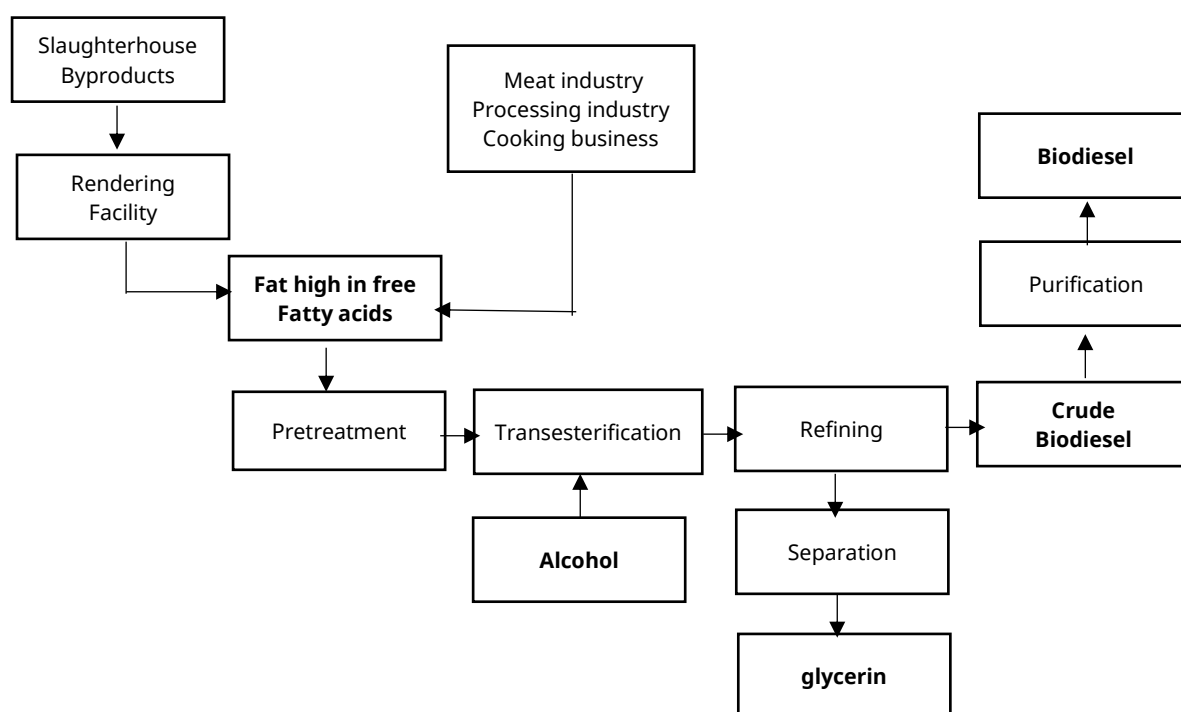


Figure 3. Major steps in the production of biodiesel from animal fat waste. [18,19,]

As lubricant

Tallow has played a vital role in lubricating steam-driven piston engines, locomotives, and steam engines since the early days of industrialization. Its resilience against being washed away by hot vapors and liquids made it indispensable for maintaining machinery performance.

During World War II, when tallow supplies dwindled due to the high demand for steam-powered ships, canola emerged as an alternative lubricant source. Canola oil shared similar properties with tallow, making it a suitable replacement during shortages. Today, tallow

remains a crucial lubricant in specific industrial processes, such as in the steel rolling industry where it enables smooth operations during the pressing of sheet steel by steel rollers. However, there is a growing preference for synthetic oils over tallow-based lubrication in rolling applications to improve surface cleanliness and performance.[21]

Candle

Before the widespread availability of wax candles, tallow candles held a prominent place as an early form of artificial lighting. Derived from rendered animal fat, typically from beef or sheep, tallow was readily accessible, making these candles a popular choice. They were crafted by pouring molten tallow into molds, creating pressed candles that illuminated countless households for centuries. Even as wax candles gained popularity, tallow candles remained in use due to their affordability.

For those unable to afford pressed candles, simpler alternatives like tallow dips were utilized. These makeshift candles were created by dipping reeds or strips of cloth into melted tallow. Serving as basic sources of light, they were commonly known as "dips" or by their nominal price, such as "farthing dips" or "penny dips." The history of tallow candles and dips reflects the resourcefulness of people throughout history as they sought ways to illuminate their homes using the materials available to them.[22]

In cosmetics

Lard, tallow and rendered poultry fat and its derivatives are used in personal care products like lipstick, eyebrow pencil and eyeliner. Lard has desirable characteristics for beauty products, like emulsion stabilization, emollient, occlusive, surfactant and viscosity increasing properties. Tallow contains the glycerides of oleic, palmitic, myristic, stearic and linoleic acids which has desirable characteristics like emollience, which are desirable for skin conditioning, emulsification, and viscosity-enhancing agent. Tallow is a common ingredient in beauty products, like eye makeup. Make up base and foundations, lipsticks, shaving soaps, shampoos, moisturizers, and other skincare products.[23]

3. SOAP

3.1 Brief history of soap

The narrative of soap's origin tied to Mount Sapo in ancient Rome which tells of rainwater mixing with animal fats and ashes, leading to the discovery of a cleaning mixture by women washing clothes downstream. Soap, one of the oldest cleansing agents, has a history spanning 4500 years and was historically linked to a society's level of civilization.

Soap became a luxury item in the 18th century due to raw material shortages but became more accessible with the development of sodium carbonate manufacturing. The chemical composition of soap, particularly its lipophilic part, determines its effectiveness. Pliny the Elder's writings detail early soap production methods, and societies worldwide adopted similar techniques.

Today, soap is widely used for body cleansing, fabric detergents, and utensil cleaning, but its alkalinity can cause skin irritation and is incompatible with hard water. Modern soap production involves neutralizing fatty acids with sodium hydroxide, and various properties are evaluated to ensure quality. [24]

3.2 Soap production

Soaps are sodium and potassium salts of long-chain fatty acids. These fatty acids are found in vegetable and animal fats. The reaction of fats with alkali is called saponification. Soaps normally do not contain free fatty acids, except for toilet soaps, where there is supposed to be a partial emollient property. Free alkalinity is also not desirable, as it causes a rash on the skin. The correct pH of the soap solution should be 12 to 12.5. Soaps are made by three different processes. [24]

3.2.1 Cold process

The process basically consists of adding just enough alkali to the melted fats to ensure saponification and create a neutral soap. Fats and oils to be used as soap stock are only heated so that the fats melt, and the oils make a crackling sound when sprinkled with a few drops of water. They are then brought into contact with lye and left to stand for several days. A saponification reaction takes place and the heat generated during the reaction accelerates the

subsequent saponification process.

The main problem with the process is the ratio of alkali to added to complete the saponification process. If oils and fats were primary substances consisting only of olein or stearin or palmitic or laurin, the whole matter would be greatly simplified. If the chemical equations would give us the exact proportions between the glyceride and caustic soda on the one hand, and the manufactured soap and glycerin on the other. But in practice, the oils used are very heterogeneous mixtures of many glycerides, and the proportions between them, even in the same oil, vary greatly according to the source, quality, and age of the substance.

When making soap, fat or oil is placed in a pan equipped with a stirrer. Then just heat the fat or oil to 25-30°C. After dissolving, pour the lye at room temperature into the pan and keep stirring the mixture until the mass thickens. The fat and oil should be at the right temperature, if they are too cold, they will solidify by adding lye. If they are too hot, saponification will occur quickly, and the result will be curd or grainy soaps. The decisive factor is the strength of the alkali. The alkali should be of suitable purity so that impurities do not get into the soap during saponification, so that they do not cause efflorescence. [24][25]

3.2.2 Semi-boiling process

According to the semi-boiling process of soap making, the fatty acids are directly combined with alkalis, which are added in such proportions as to ensure the complete reaction of the fatty acids.

First, it is necessary to find out the percentage of alkali needed to saponify the oil. For example, coconut oil requires 17.48 to 19.05% of its own weight for NaOH to achieve complete neutralization. The above fact will give a good idea of the quantity of alkali to be taken to saponify a given quantity of oil. Liquor of suitable strength is formed from suitable alkali. Fats and oils are brought to a boil and the base is slowly mixed in bit by bit. Boiling is continued with alkalis of increasing strength until all the alkalis are absorbed. Water is added from time to time to keep the mass thin and homogeneous.

During saponification, the oil swells considerably. Precautions can be taken to prevent entrainment. The use of a stirrer is recommended for this purpose; adding oils in small doses is helpful. [24][25]

3.2.3 Cooking process

Oils and fats are placed in a large pan or reactor and melted by heating. NaOH/KOH is gradually added to the mass maintained in a state of boiling by stirring and boiling. The strength of the lye and the amount added from time to time depends on the nature of the oil and fat. Weak lye must be added slowly at first until saponification is well started. This is indicated by the composition of the emulsion. Once the saponification process begins, continue to boil, and continue to add more concentrated lye in small amounts until it is absorbed, so there is not much evaporation needed at the end to get the right consistency. But the lye should not be too strong, as the soap paste will then be cut into a curd upon which the alkali cannot act satisfactorily. Water is added to this from time to time. The emulsion should gradually thicken as the saponification process progresses. Usually, the solution becomes clear and brownish in color after saponification is complete. Completion of saponification is also determined by the following test, which is called the "ring test". A quantity of soap is scooped up with a trowel and a drop of it is caught on a glass board, slate, or clean floor. This drop needs to be watched as it cools. If, on cooling, the edge of the drop first solidifies to form a white ring, and the middle part remains transparent until it gradually solidifies, the solidification proceeding from the edge to the center, the saponification is complete. If a circular edge is not formed first, another addition of alkali is needed.

The pan now contains saponified fat or soap, excess alkali, and glycerol mixed. If the soap is to be of good quality, either the excess of alkali must be removed from the soap, or the lye left after the operation must be separated from the soap, which may be treated to obtain glycerol if possible. When saponification is achieved, the soap is still boiling and of a thick consistency, a saturated common salt solution is added little by little to precipitate the soap. If salting is started when the soap is diluted, a large amount of salt will be required. Instead of using a salt solution, the salt can be spread evenly over the surface. The boil is slowly reduced. The soap loses its smooth transparent appearance and becomes grainy and opaque. This is technically known as "opening" the soap.

The granular soap is then boiled with sufficient water. The granules begin to swell and join or "close" as it is called. The soap has a smooth appearance. If necessary, the soap grains can be broken with a crutch. Subsequently, when it cools and frames, it gives ordinary soaps from the store. [24][25][26]

3.3 Soap additives

Optical brighteners

Although the surfactant system in detergents cleans clothes effectively, the white fabric tends to "grey" or lose its white appearance after many washes. Optical brighteners are added to laundry detergents to visually improve the "whiteness" or brightness of the fabric. Essential to most fabrics, these materials absorb ultraviolet radiation and convert it into visible blue-white reflectance. [24]

Sodium sulfate (Na_2SO_4)

Although it is used by some manufacturers as a filler, contributes little to the effectiveness of the detergent. It is commercially available from natural sources and as a by-product in rayon processing. In dry mixtures and products of the agglomerated type, Na_2SO_4 is used to improve the flow characteristics of the finished product. In spray-dried products, it as an inert "filler" and helps control density and flow characteristics. [24]

Builder

They are usually added to detergent formulations to extend or improve cleaning effectiveness over a wide range of conditions of use. The combination of builders and surfactants shows a synergistic effect to increase the overall detergent and cleaning efficiency compared to the same amount of each compound alone. Among the main properties and characteristics that are desirable for a compound to be considered a detergent builder must be, for example: Ability to control water hardness and other metal ions, buffering capacity in the correct pH range, deflocculation ability, consumer safety, environmental acceptability, adequate price/performance, etc. [24]

Typical builders include phosphates. The first representative used was tetrasodium pyrophosphate ($\text{Na}_4\text{P}_2\text{O}_7$ – TSPP) or tetrapotassium pyrophosphate ($\text{K}_4\text{P}_2\text{O}_7$ – TKPP). These are phosphates intended mainly for detergents. They have been available since the 1930s century. Their main task was water softening, i.e. Ca sequestration²⁺ and Mg^{2+} ions. A negative side effect of phosphates is the so-called "water bloom" effect. When too much phosphates released into rivers caused eutrophication and algae and cyanobacteria growth and destruction of the river ecosystem. [24]

Zeolites are an important alternative substitute for phosphates. They are not soluble in water, but they reduce the hardness of calcium water by means of ion exchange. The calcium ion passes through the pores of the zeolite and is exchanged with the sodium ion. Magnesium ions are not significantly removed by zeolites due to the large radius of magnesium ions. [24]

Enzymes

Proteolytic and amylolytic enzymes have been proposed for use as auxiliaries in stain removal detergent systems. These complete protein molecules act as a catalyst and tend to break down specific dirt and stains into a form that is easier to remove from fabrics. [24]

Anti-caking agents

Due to reduced levels of phosphates and the use of non-phosphate builders in some powder detergents, the flow properties and caking tendencies have changed. Products formulated with increased levels of anionic actives and higher sodium carbonate content tend to exhibit stickiness in the detergent carton. Anti-caking agents have been added to reduce this tendency, especially in warm humid climates. [24]

Aromatic substances

According to the origin, we distinguish between natural fragrances from plant and/or animal sources and fragrances prepared by chemical synthesis (naturally identical or non-identical). In the same way, dyes have the task of consumer attractiveness or masking the smell. [27]

Dyes

They are soluble in water, alcohol, oil or other organic solvents in cosmetics. In cosmetics, dyes are used to enhance appearance and for decorative purposes. This includes chlorophyll, carotenoids, henna, etc. [27]

3.4 Types of soaps

There are many types of soaps, depending on the application, there are hard and soft soap. The hardness of soap is often achieved through the addition of hardening agents, so many natural soaps tend to be softer.

Kitchen soaps- they are categorized into two: cleansers and detergents. Cleaners are often made with mild abrasives and are formulated to eliminate oil or solid particles and hard-to-remove stains. The cleansers come in many different types depending on the type of abrasives they contain while

Detergents are made to remove tough grease and release the solid dirt particles in the foam that is produced by the detergent.[27]

Laundry soaps- laundry soaps are formulated to eliminate grease, solid particles, and organic compounds from clothes. They can be found in liquid, powder, and gel forms.[27]

Personal soaps- it is made in many forms and special formulations for specific personal hygiene needs. one type is the antibacterial soap that is made to prevent bacteria and viruses from spreading. There are also body and hair soaps that have a mix of ingredients that cleans both the skin and hair.[27]

Novelty soap- Novelty soaps are especially manufactured for kids and include soaps in the shapes of various items, such as rubber ducky or the soap-on-the rope. They are made not only to clean dirt and grime but also for amusement and enjoyment.[27]

Potassium soaps (gooey)—they are made from liquid oils and potassium hydroxide. They are used for technical purposes, to remove large impurities. [27]

Sodium soaps (hard)—they are made from solid fats and sodium hydroxide.

Perfumed soaps- perfumed soaps are produced by adding a few additional ingredients and perfume.[27]



Figure 4 liquid detergent



Figure 5 antibacterial soap

4. SOAP PHYSICAL/ CHEMICAL PROPERTIES

Soap, typically made from fats or oils combined with an alkali, possesses several properties that make it useful for cleaning, these properties influenced the quality and the applications.

4.1.1 pH of Soaps

Soap is a base and exact pH would be different depending on the soap. The pH level of soap can vary with the brand and with the function of the soap. However, soap makers measure the acidity or alkalinity of soap by its pH level on a scale of 0 to 14. The average pH levels in bath soaps range from 3.61 to 12.38. For a general soap the pH is from 5 to 8 and for hand soaps the pH is anywhere from 10 to 12. A 2002 International Journal of Dermatology study found pH levels in bath soap ranging from 3.61 to 12.38. High pH soaps caused the most irritation. In liquid dish washing liquids, a pH in the range of about 7-8. [28,29]

4.1.2 Basicity of soaps

Soaps undergo a hydrolysis reaction in water. As a result, soap solutions tend to be alkaline. Detergents solutions on the other hand tend to be more neutral. Phenolphthalein indicator when in contact or presence of acid it will turn colourless and with base, it will turn into a pinkish violet colour. When the solution of soap is treated with 2-3 drops of phenolphthalein, it is found to show no change, indicating that the selected soaps are found to be neutral.[30]

4.1.3 Total Fatty Matter (TFM) of soaps

Total Fatty Matter (TFM) is one of the most important characteristics describing the quality of soap and it is always specified in commercial transaction. It is defined as the total amount of fatty matter, mostly fatty acids, that can be separated from a sample after splitting with mineral, usually hydrochloric acid. The fatty acids most commonly present in soap are oleic, stearic, and palmitic acids and pure, dry, sodium oleate has TFM 92.8%, while top quality soap noodles now increasingly used for making soap tables in small and medium size factories, are typically traded with a specification TFM 78% minimum, moisture 14% maximum. But besides moisture, finished commercial soap, especially laundry soap, also contains fillers used to lower its cost or confer special properties, plus emollients, preservatives, etc. and then the TFM can be as low as 50%. Fillers which are usually dry powders, also make the soap harder, harsher on the skin and with greater tendency to become 'mushy' in water and so low TFM is usually associated with hardness and lower quality. In older days in Europe and in some countries, soap

with TFM 75% minimum was referred to as Grade I and 65% minimum as Grade2 and less 60% Grade 3. [29]

4.1.4 Emulsification of soaps

Soap is an excellent cleanser because of its ability to act as an emulsify agent. An emulsifier is capable of dispersing one liquid into another immiscible liquid. This means that while oil (which attracts dirt) does not naturally mix with water, soap can suspend oil/dirt in such a way that it can be removed. For a soap to perform its cleaning activity it should be able to form emulsion in presence of oil. As a result of their molecular structures, soaps and detergents are both capable of emulsifying or dispersing oils and similar water-insoluble substances. Results showed that all the selected soap samples were found to have good cleansing action as they formed emulsion when shaken with oil.[32]

4.1.5 Moisture content of soaps

Soaps often require a precise quantity of moisture to work at their most efficient levels; too little moisture leaves the soap too dry to use, while excessive moisture will make solid soaps more difficult to unmould and dry out. As common sense would dictate, one would expect a high level of moisture in liquid soap products. Moisture content affects soap making. The process of making soap (called “saponification”) is highly dependent on the moisture level in the mixture. A major chemical ingredient in soap-making is alkali, such as lye, which reacts with fatty acid esters to produce neutral salts of fatty acids, the principal ingredient in soaps. The lower the water content of the reaction mixture, the higher the pH and the stronger the alkali. If the moisture level in the saponification reaction mixture is too high, the alkalinity will be reduced, and the reaction will proceed too slowly. However, a high concentration of alkali chemicals is corrosive and damaging to people and equipment and must be handled with care. If the soap recipe does not have enough water the solid soap produced may form cracks. The moisture content of solid soap is adjusted by evaporation after the chemical reaction is complete.

There is no specific measurement of moisture content as per the national standard. It should not be too high or too. [31]

4.1.6 Foaming capacity

Lather is the foam created by soap when stirred in water or while bathing or washing hands. It is an important parameter for acceptability of soaps. All the brands passed in the lather test. Fair beat alone was found to produce thick rubbery foam. The foam stability was determined by noting the time taken for disappearance of 2mm of froth.[32]

5. EVALUATIONS OF THE LITERARY STUDY, OBJECTIVES AND HYPOTHESES OF THE THESIS

The available literature on obtaining and producing vegetable or animal fats for soap production appears limited, with either insufficient sources or information that does not suit the theoretical framework of the thesis.

The aim of the thesis was to create and analyse soaps primarily using lipophilic by-products from fat processing. Soap production as an anionic surfactant is relatively straightforward, its properties vary based on the fat composition and the amount of alkali used in the reaction.

The objective was to examine the effects of specific processing conditions such as quantity of Potassium hydroxide used for saponification, saponification temperature, and sodium chloride for salting out on the yield and properties of laboratory prepared soap.

Subsequently, these prepared soaps were analysed using the factorial scheme to deduct the effect of the processing conditions on the physical and chemical properties of the prepared soaps as well as to deduct the optimal processing conditions for soap production using Deer fat.

II. PRACTICAL PART

6 MATERIALS/ METHODOLOGY

6.1 Instruments, aids and chemicals used for production.

Analytical balance kern ALS 250-4A, Laboratory balance VWR, Electric heating plate with magnetic stirrer IKA C-MAF HS7, Magnetic stirrer MM4, Ph meter 526, knife, kitchen board, metal sieve, Sieve clothes, Spoon, Laboratory beakers with ranging volumes of 50,100,250,1000ml, Laboratory measuring cylinders with ranging volumes of 50,100,250,1000ml, Burette, Thermometer, Electric cooker Petri dish.

Potassium hydroxide (manufactured by Lach-Ner, s.r.o.), Sodium chloride (manufactured by Lach-Ner s.r.o.), 98% Acetic acid (manufactured by Lach-Ner, s.r.o.) 96% Ethanol, Distilled water.

6.2 Raw material

The raw material used for the laboratory production was fat from the European fallow deer (Dama dama) which was supplied by Venison CZ Ltd. (Míšovice, Czech Republic).

6.3 Fat tests

6.3.1 Test for moisture

A moisture content test was carried out to determine if there is any form of moisture in the pure deer fat.

To determine the moisture content, weigh out 5g of the fat sample into a petri dish, taking note of the weight of dish, dry the sample in an air oven at 100-105°C for 5hours after which the moisture content is calculated.

$$\% \text{moisture} = \frac{\text{loss in weight} \times 100}{\text{initial weight of fat}}$$

6.3.2 Acid value and Saponification value

The acid number indicates how many mg of KOH is needed to neutralize the free fatty acids found in 1 g of fats or isolated lipids. The acid number is an important indicator of the status of fats (lipids), which directly affect the quality of raw materials and products.

Differentially weigh out 2g of the sample into a 250ml round-bottomed flask, then add 5ml if

xylene, 30ml of neutral ethanol and 20 drops of phenolphthalein with 3-4 boiling ball in it.

After which the solution was gently heated (in a heating nest) under reflux to 70-80°C for 10-15 minutes and quickly titrated under hot conditions directly in the flask with the already prepared 0.5M ethanolic KOH solution to a pink colour stable for 10 seconds. The volume of the titer was recorded. Subsequently, to the titrated solution add additional ethanolic KOH, enough to give a total quantity, including consumption per acid number of 20.0ml.

Put a reflux condenser on the flask and keep it boiling on the heating nest for 2 hours, as the time elapsed add another 1ml (10 drops) of phenolphthalein and titrate hot (70-80°C) with 0.5M aqueous HCl until the pink colour disappears. Finally boil the solution again and, if the pink colour reappears, re-titrate. Repeat this process until the pink colour no longer appears.

The blank was as well titrated without the sample.

$$AV = \frac{(a - b) \cdot c_{KOH} \cdot M_{KOH}}{n}$$

Where:

a – 0.5M KOH consumption of the sample [ml]

b – consumption of 0.5M KOH for blank experiment [ml]

c_{KOH} – concentration KOH [$\text{mol} \cdot \text{l}^{-1}$]

M_{KOH} – molar mass KOH [$M_{KOH} = 56.106 \text{ g} \cdot \text{mol}^{-1}$]

n – sample weight [g]

$$SV = \frac{(b - a) \cdot c_{HCl} \cdot M_{KOH}}{n}$$

Where:

a – 0.5 M HCl consumption of the sample [ml]

b – consumption of 0.5 M HCl for blank experiment [ml]

c_{HCl} – concentration HCl [$\text{mol} \cdot \text{l}^{-1}$]

M_{KOH} – molar mass KOH [$M_{KOH} = 56.106 \text{ g} \cdot \text{mol}^{-1}$]

n – sample weight [g]

6.3.3 Determination of fat melting point

The fat melting point was determined using capillary method, firstly immerse a capillary tube with a thickness of 1mm (length 50-100mm) in hot fat to a depth of about 10-15mm which was put in the fridge for 24 hours. Subsequently place the tube in a beaker with cold water, a thermometer was attached close to it, then heat up the beaker as the water has been stirred with the aid of a magnetic stirrer, monitor the layer of solidified fat in the capillary tube, once the fat starts melting, the layer of fat becomes transparent or pushed upwards, the temperature at that point was recorded as its melting point.

6.3.4 Determination of Fat impurities

This test was done to investigate the number of impurities that could be present in the pure fat, which might affect the quality of soap produced. Firstly, weight out 10g of pure fat then dissolved in petroleum ether, after which was kept in the refrigerator for one hour. Subsequently filter through a high-density filter paper which the weight was initially recorded, after filtration, dry the paper at about 40°C for about 2hours. Finally the percentage difference was calculated.

$$\% \text{impurities} = \frac{\text{increase in weight} \times 100}{\text{mass of fat}}$$

6.4 Experimental method

To produce soap from venison fat, it's essential to have a selected amount of the basic raw material (fat), and then recalculate the amount of water and saponification solution in a defined ratio. Three selected factors were monitored during the production process. These three factors were varied during the production process to produce sufficient samples for suitable analysis.

Design of experiments (DOE) is a tool that enables the examination of the influence of independent variables (process factors) on dependent variables. Therefore, it enables the identification of significant factors of the process and its optimization [33]. Various experiment planning designs are used in practice, e.g., Central composite design, Three-level full factorial design, Box-Behnken design, or Taguchi design [34]. The Saponification temperature, amount of salting and amount of KOH are the factors under study which influence the yield of soap as well as the soap properties. These factors were studied using the three-level full factorial design of the experiments. This will achieve a more effective optimization of the soap preparation process from the Deer fat by-product. The independent variables Factor A amount of KOH; 40,45,50g, Factor B Saponification Temperature; 86,90,94°C, Factor C Amount of NaCl; 55g,70,85g while the selected dependent variables were as follows: Soap yield [g], pH, Total soap alkalinity [%], foaming capacity [%], foam stability [%], penetration[N], free fatty matter [%] and moisture content.

The soap analysis was performed three times, and the mean value were calculated using Microsoft Office Excel 2013, subsequently Minitab 22.1.0. statistical software for windows was used to perform regression analysis of the data obtained. The statistical significance was evaluated using analysis of variance (ANOVA). The level of significance was setup at 5% (p-value ≤ 0.05); factors with a value < 0.05 influences the process variable evaluated with 95% probability. The same software was used to evaluate the graphical analysis of the data by creating contour plots showing the relationship between dependent variables and independent variables by viewing discrete contours of the dependent response variables.

6.5 Production flow chart

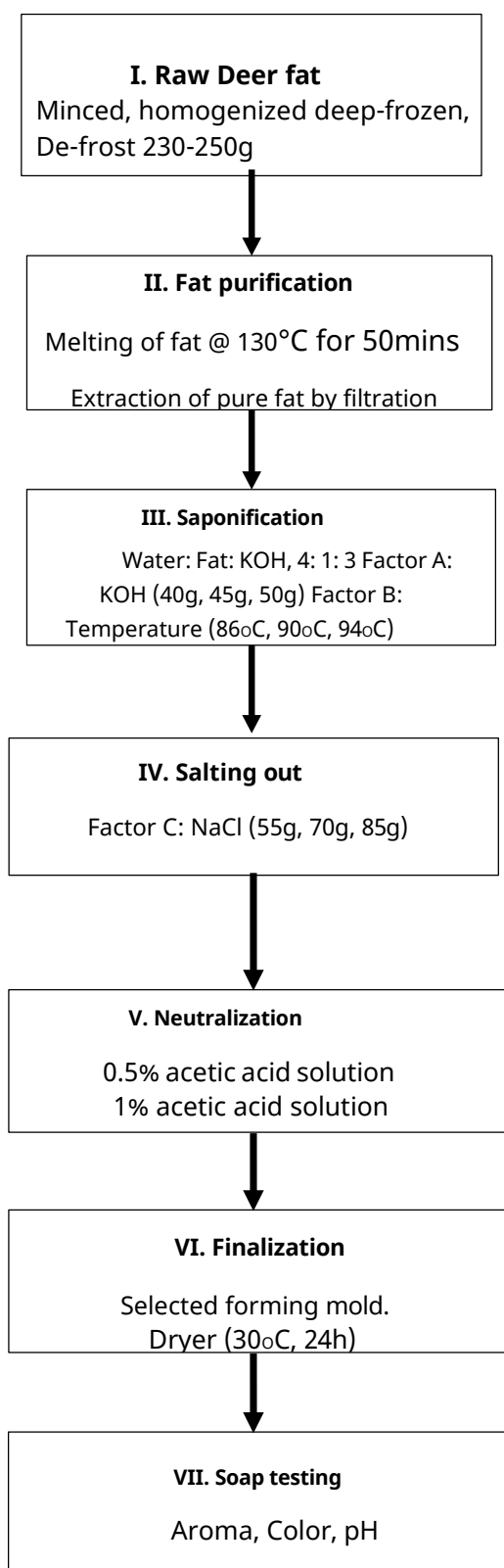


Figure 6. flow chart of soap production process

6.5.1 Production process

Soap samples were prepared according to a recipe that was created in such a way that it could be modified to produce samples adjusting the three parameters which are Amount of Potassium hydroxide (Factor A), Saponification Temperature (°C) (Factor B), Amount of Sodium chloride (Factor C).

I Preparation

The amount of the basic raw material (venison fat), water and saponification solution were in the ratio 1:4:3(Fat: Water: Saponification solution). The saponification solution contained granular potassium hydroxide at a range of 40-50% by weight of the fat sample. The salting agent required for the final salting was in the range of 55-85% by weight of the fat sample.

The last monitored parameter is the saponification temperature which was in the range of 86-90°C.

II Fat purification

The first step in manufacturing was weighing out about 230g-250g of the raw fat in a beaker and preparing the saponification solution as well as the salting agent according to the monitored parameters. Subsequently, the weighted fat was placed in the oven at 130°C for 50minutes to dissolve the fat, after which the purified fat was extracted with the aid of a metal sieve with a cloth, the impurities (muscle and other non-lipophilic parts) were transferred to a petri dish, dry at 100°C for 24 hours and weighed. The average content of the impurities was 20-25% by weight of the sample. After extracting the pure fat in a 2000ml beaker.

III Saponification

Firstly, 400ml of distilled water was added to the fat and 15% by volume of the saponification solution, then the mixture was placed on an electric heating plate with a stirrer and heated at 80°C (processing temperature) for 15minutes with continuous stirring, as the time elapsed, another 15% by volume of the saponification solution was added, maintaining the processing temperature as well as stirring for another 15minutes. Subsequently, 40% by volume of the saponification solution was added and the temperature was set according to the saponification temperatures(86,90,94°C) and stirred for 25mins, finally the remaining 30% by volume of the saponification solution was added as stirring continues for 75minutes according to the selected saponification temperature. As the time elapsed the electric heater was turned off while stirring

continues for 15 minutes maintaining the processing temperature.

IV Desalination

Before salting commences, the mixture was top up with 500ml by volume of hot water (85°C) which correspond to five times by weight of the fat sample. Still maintaining the processing temperature, the salt (sodium chloride) was added in teaspoon for an interval of 30seconds per teaspoon till all the amount of salt was added according to the ranges used. During this period the soap mixture could thicken, when the magnetic stirrer wasn't able to stir the mixture, a glass rod was used to ensure a homogenous mixture and the mixture was stirred for 5minutes. As the time elapsed, the beaker was removed from the heating plate and let to stand for 1hour without stirring, while standing the mixture separated into two layers: a mother liquor as the bottom layer while the top layer is the raw soap(cake). The soap was carefully filtered from the mother liquor with the aid of a separating funnel and sieve cloth. The pH of the mother liquor was recorded.

V Neutralization

The soap cake was broken up with a laboratory stick into smaller pieces for proper penetration and washing in a Büchner funnel, which was fitted in a sieve cloth with tiny pores to retain the soap. The soap was initially washed and neutralized with 500ml of chilled 1%acetic acid, followed with 500ml of 0.5% acetic acid. After neutralization, soap was transferred into a pre-weighed silicon mold and then weighed. Subsequently the moist soap was placed in a drying oven with air circulation at a temperature of 30°C for 24hours, after which the soap was reweighed and placed in room temperature for 14days.

VI Finalization

After neutralization, soap was transferred into a pre-weighed silicon mold and then weighed. Subsequently the moist soap was placed in a drying oven with air circulation at a temperature of 30°C for 24hours, after which the soap was reweighed and placed in room temperature for 14days.

VII Testing the soap.

After the 14days, the prepared soap samples were reweighed and recorded, after which the physicochemical analysis was carried out to evaluate the quality of the soap samples.



Figure 7. Raw Deer fat



Figure 8. Melted deer fat and extraction of pure fat.

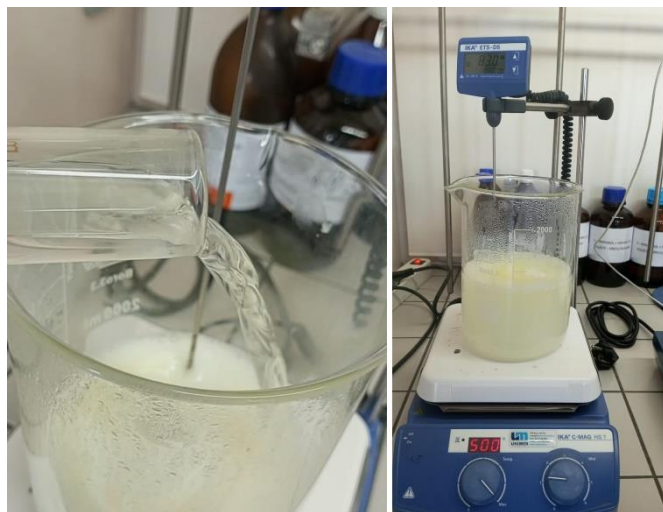


Figure 9. Addition of KOH solution and setup of the soap production

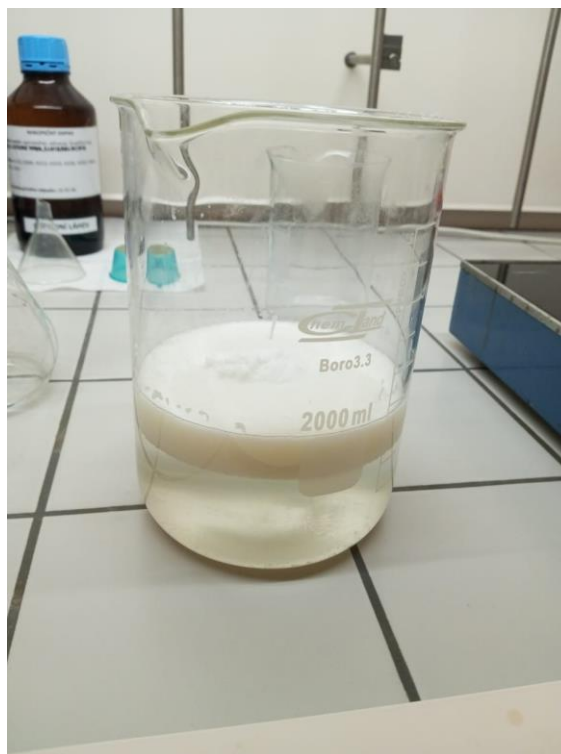


Figure 10. Separation of the mixture into two layers after salting



Figure 11. Soap after neutralization process



Figure 12. Dried soap

6.6 Soap test

6.6.1 Determination of pH

The pH value of the soap changes over time since the soap was manufactured, in this case it was determined 14 days from the date of manufacture. To determine the pH value of the soap, a method was chosen where 0.3 g of the sample was dissolved in 30 ml of distilled water, which was recorded with the aid of the pH tester. the measurement was done at least three times for each sample. [35]

6.6.2 Determination of total alkalinity

During the production of soap, a small amount of alkaline substances remains in the soap. Using this method, the percentage representation of alkaline components such as hydroxides, sodium oxide, carbonates and hydrogen carbonates is determined. To determine the total alkalinity, a sample weighing 10 g is taken into a laboratory beaker. Pour the contents of the beaker with 100 ml of 96% ethanol and let it boil for 10 minutes. The sample of solid soap does not have to dissolve completely on its own; for better dissolution, stir the contents of the beaker slightly with a glass rod. Subsequently, 5 ml of 1N H₂SO₄ is added, and the sample is allowed to boil again for 5 minutes, as time elapsed allowed to cool down clearly pour out the solution to separate the fatty acid content then add phenolphthalein indicator to the solution and titrate with 1N NaOH until the solution turns pink color. [24][36]

$$\text{Total alkalinity} = 3,1 * \frac{(v_a - v_b)}{w} [\%]$$

v_a - volume of H₂SO₄ used in ml

v_b - volume of NaOH consumed during titration in ml

w – exact weight of soap sample

6.6.3 Determination of Foaming capacity

Modified procedure: To make the soap samples produced in the laboratory more economical and to use a graduated cylinder with a smaller volume, the method has been slightly modified. When the amount of sample was reduced to 1 g, which was put into a cylinder and poured with distilled water to a mark of 20 ml. The resulting solution was shaken 20 times, and the height of the foam was measured from the 20 ml mark.[24][36]

6.6.4 Determination of Foaming stability

The method for determining the foam stability follows the method for determining the foaming capacity of soap, when the foamed solution in the cylinder, the height of which was measured, is left at rest for 30 minutes. After this period, the height from the initial line is measured again and the difference in foam height values is calculated. [24][36]

6.6.5 Penetration Test

The method of determining the hardness of the soap was carried out on a texturometer TA.XT. Plus, a Texture Analyzer made by Stable Micro Systems in the UK. The penetration test was performed using a penetration roller with a diameter of 10 mm. At the beginning of the test, the penetration roller was set to an approximate position of 5 mm above the test sample. This distance was chosen so that the test would not take too long due to the speed of the probe. The total penetration depth of the sample was set to a depth of 10 mm. A speed of 1 mm/s was selected for the movement of the roller towards the sample, a lower speed of 0.8 mm/s was selected for contacting and penetrating the sample, and the speed of the probe when returning to the original position was set to 1 mm/s. Penetration of each sample was performed at least 3 times. [37]

6.6.5 Determination of moisture content

A moisture content test was carried out to determine if there is any form of moisture in the prepared soap.

To determine the moisture content, weigh out 5g of the soap sample into a petri dish, taking note of the weight of dish, dry the sample in an air oven at 103°C for 5 hours after which the moisture content is calculated.[36]

$$\% \text{moisture} = \frac{\text{loss in weight} \times 100}{\text{initial weight of soap}}$$

6.6.6 Determination of total fatty matter

In each soap sample, 5 g was weighed and dissolved in 100 cm³ of hot water. Thereafter, 40 cm³ of 0.5 N HNO₃ was added to make it acidic. The mixture was heated until fatty acids were floating as a layer above the solution. It was cooled in ice water to solidify the fatty acids. The fatty acids were separated, and the aqueous solution was treated with 50 cm³ chloroform to remove the remaining fatty acids. The separated fatty matter was mixed, solvent was

evaporated, and the yield noted. The total fatty matter was calculated using the following method.[38]

Weight of dish (x)

Weight of dish + fatty matter after drying (y)

Weight of soap sample

$$\% \text{ of fatty matter} = \frac{(y-x)*100}{\text{weight of soap}}$$

7. RESULTS AND DISCUSION

7.1 Analysis of the raw material (Pure Deer Fat)

Analyzing the characteristics of pure fat gives an insight into the fat composition and quality.

Moisture content

The pure fat was found to have no moisture content.

Acid value

The acid value was determined to be 2.7 ± 0.2 mg/g which indicates the amount of free fatty acids present in the fat. A higher acid value suggests higher levels of free fatty acids, which can indicate the fat's quality or purity.

Saponification Value

The saponification value was measured at 217.2 ± 2.1 mg/g. This value indicates the average molecular weight of the fatty acids present in the fat, which is useful in determining the purity of the fat and its suitability for soap-making.

Melting point

The melting point of the fat was found to be $40^{\circ}\text{C} \pm 1$. The melting point is crucial as it can indicate fats composition and its potential uses in various applications. The pure fat having a consistent melting point suggests a relatively pure composition.

Degree of melting point

The rate of melting was determined to be $2.55^{\circ}\text{C}/\text{min}$. This parameter can provide insights into the fat's thermal properties and its behavior during heating.

Fat Impurities

The fat impurities test yielded a result of 1.4%. This suggests that the fat contains impurities, but at a relatively low level, this might be caused from slight error during the extraction process.

7.2 Soap Summary Results

PROCESSING FACTORS

Exp. No	Factor A, Amount of KOH Fraction	Factor B, Saponification Temperature (°C)	Factor C, Amount of NACL Fraction	Weight of raw fat (g)		Weight of separated impurities (%)
1	0.4	86	0.55	220		28.2
2	0.4	86	0.85	280		35.3
3	0.4	94	0.55	220		32.9
4	0.4	94	0.85	230		39.6
5	0.5	86	0.55	250		45.0
6	0.5	86	0.85	250		43.8
7	0.5	94	0.55	250		35.1
8	0.5	94	0.85	250		34.3
9	0.45	90	0.70	250		25.8

PROCESSING FACTORS

Exp. No	Factor A, Amount of KOH	Factor B, Saponification Temperature	Factor C, Amount of NACL	Weight of Freshly prepared soap (g)	Weight of dried soap after drying at 30°C) for 24hrs	Weight of dried soap after 14days(g) At room temperature	W Difference (g)
1	0.4	86	0.55	137.1	84.1	75.3	8.8
2	0.4	86	0.85	191.2	126.2	109.0	17.2
3	0.4	94	0.55	229	148.5	94.2	54.3
4	0.4	94	0.85	146.7	124.1	91.3	32.8
5	0.5	86	0.55	175.6	76.8	72.0	4.8
6	0.5	86	0.85	156.8	140.9	106.4	34.5

7	0.5	94	0.55	190.4	163.5	120.1	43.4
8	0.5	94	0.85	194.6	143	110.7	32.3
9	0.45	90	0.70	205.5	151.6	116,4	35.2

Table 7: Summary technological production conditions and soap yield

	pH of the soap solution	Total soap alkalinity [%]	Foaming capacity [%]	Foam stability after 30mins [%]	Penetration [N]
1	9.35 ± 0.03	0.70	20.2	15.0	12.42
2	9.44 ± 0.03	0.59	55.0	50.0	32.19
3	9.88 ± 0.03	0.67	45.0	40.0	89.32
4	9.62 ± 0.03	0.11	50.0	47.0	56.19
5	10.04 ± 0.03	0.21	35.0	30.0	69.93
6	9.99 ± 0.03	0.39	90.0	84.0	116.05
7	10.14 ± 0.01	0.09	215.0	207.0	190.38
8	10.21 ± 0.02	0.04	300.0	298.0	199.36
9	10.02 ± 0.06	0.60	140.0	136.0	72.57

	% total fatty matter	Moisture content (%)
1	62.52	4.92
2	81.64	6.22
3	76.77	7.12
4	82.18	10.30
5	62.61	7.52
6	72.47	9.40
7	57.49	8.07
8	77.39	8.69
9	79.04	5.33

Table 8 Summary of the soap testing parameters data

7.3 Statistical analysis of the processing conditions on weight of dried soap yield

The plot graph of the dependence of the weight of soap yield on the amount of NaCl and NaOH.

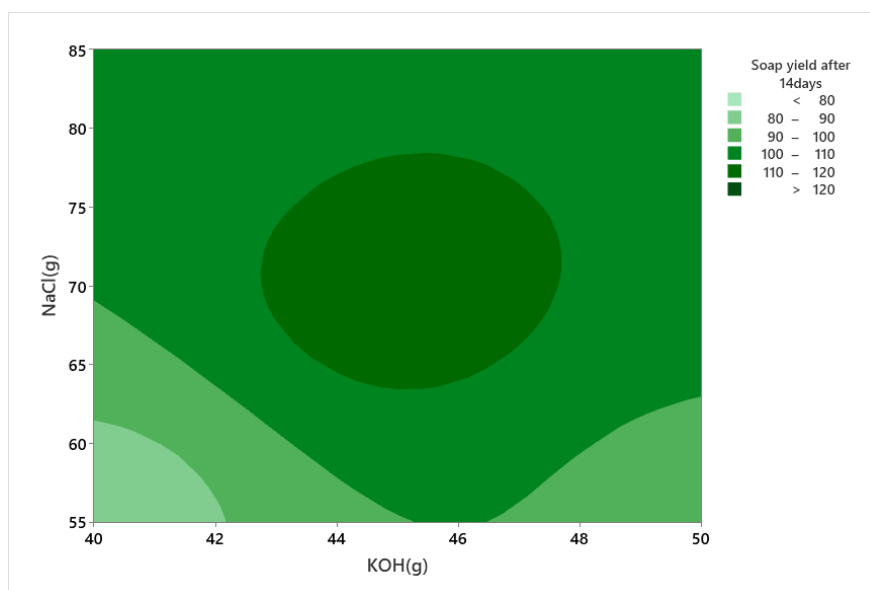


Figure 13: Graph of the dependence of the weight of soap yield on the amount of NaCl and NaOH

Regression equation: $-128 + 1.67 \text{ Temperature } (^{\circ}\text{C}) + 0.465\text{NaCl (g)} + 0.98\text{KOH (g)}$

P value: KOH=0.453, Temperature= 0.319, NaCl=0.302

Discussion:

The experimental results suggest a significant influence of both KOH and NaCl quantities on the resulting mass of dry soap. Figure 13 in the analytical chart shows that there is 15-20% increase in the soap yield when the two processing conditions were increased and maximum and the weight of the soaps were at the range of 100-120grams. This outcome aligns with expectations, as higher concentrations of both chemicals typically yield more soap.

However, at the average KOH quantity, the soap mass remains relatively consistent ranging from 90-100grams except sample 7 which has higher yield. This consistency indicates when using moderate amounts of KOH, variations in NaCl quantity have less impact on soap production. This observation could be attributed to the purification process of the raw fat.

Conversely, the lowest amount of soap was obtained when moderate quantities of both KOH and NaCl were used. This outcome suggests that incomplete salting out may have occurred, possibly due to residual impurities interfering with the process. To optimize soap production in future experiments, ensuring thorough purification of the fat sample and adjusting KOH and NaCl quantity accordingly could enhance the soap yields.

7.4 pH of the soap solution

The bar chart below shows the comparison of the soap solution pH values, the y axis which denotes the pH values and x axis denotes the soap samples, while the contour plot shows the dependence of pH on

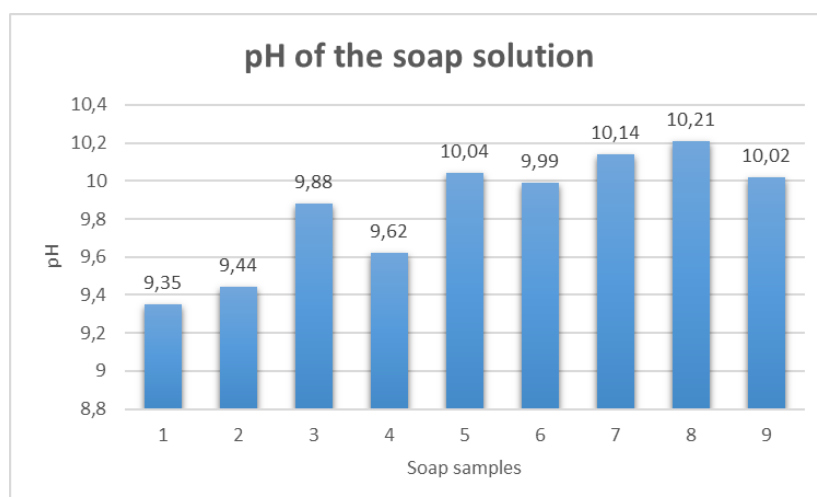


Figure 14. Bar chart comparing the pH of the soap solutions.

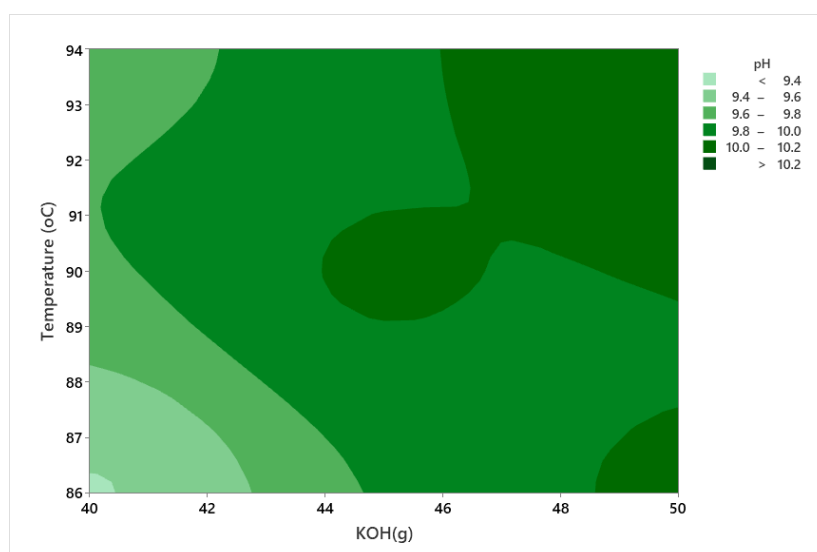


Figure 15: Graph of the dependence of pH on the amount of KOH and Temperature

Regression Equation

$$\text{pH} = 4.69 + 0.0322 \text{ Temp (oC)} - 0.00125 \text{ NaCl(g)} + 0.05225 \text{ KOH}$$

P value: KOH= 0.003, Temperature = 0.041, NaCl= 0.707

Discussion:

The pH level of my samples tested fell within a narrow range, indicating consistency ranging from 9.35-10.21. There was a significant ($p < 0.05$) difference between the results. Compared to the other studies, some close results for pH were found in the testing of soaps made of waste cooking oils [39], where the results were in a range from 9.96 to 11.30. Human normal and healthy skin has a pH in the range of 5.4 to 5.9 [40], and any introduction of soap with high pH can affect the skin pH balance and its flora. On the other hand, most tested commercial soaps had a pH between 9 and 10 [40]. All test samples were within the recommended levels, which can serve as a commercial soap. One reason for the slight increase in pH level could be the absence of additives in the lab-produced soaps that are commonly found in commercial soaps. These additives are likely responsible for reducing or modifying the pH of the soap to make it more suitable for human skin.

The analytical chart above in fig.15 illustrates the relationship between pH values and the parameters of temperature, and the amount of KOH used during the soap process. It shows that higher temperatures and larger amounts of KOH result in higher pH values, while lower temperatures and smaller amounts of KOH lead to lower pH values. Temperature and KOH are statistically significant ($p < 0.05$) showing a huge attribute it has on the pH value. This suggests that pH is influenced by the conditions of the saponification reaction. Additionally, high pH values in soaps can indeed be attributed to incomplete hydrolysis during the saponification process. This means that not all the reactants have been fully converted into the desired products, leaving some unreacted components that contribute to the alkalinity of the soap solution.[35][36]

7.5 Total soap Alkalinity

Total alkali content is one parameter that determines the abrasiveness of any given soap. The bar chart below in fig.16 shows the comparison of all the laboratory prepared soap, while the contour plot in fig 17 shows the dependence of total soap alkalinity on temperature and amount of NaCl.

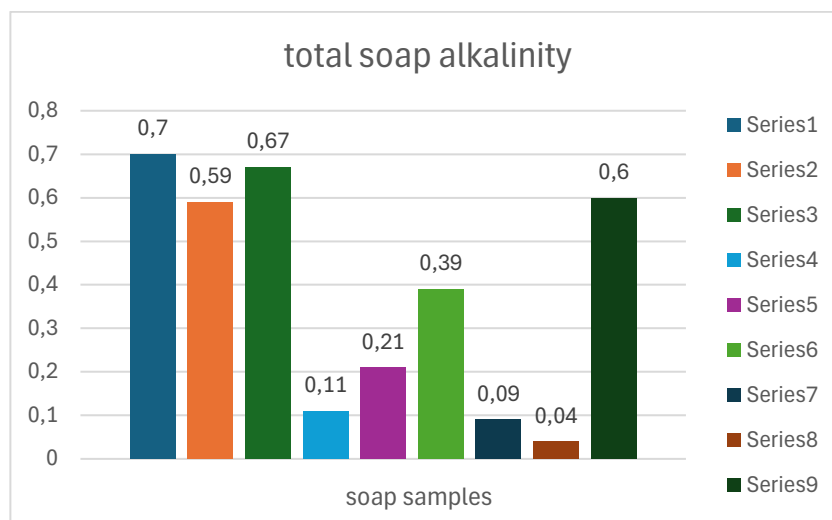


Figure 16. Bar chart comparing the total soap alkalinity of the soap

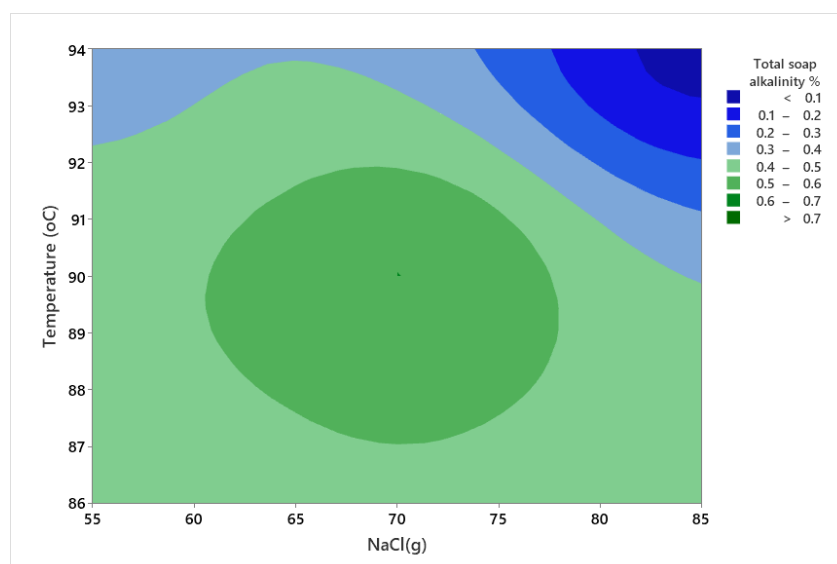


Figure 17: Graph of dependence of total alkalinity on amount of NaCl and Temperature

Regression equation

$$\text{Total soap alkalinity} = 5.0 - 0.0309 \text{ Temp } (^\circ\text{C}) - 0.00458 \text{ NaCl (g)} - 0.0338 \text{ KOH(g)}$$

P (value): KOH = 0.062 Temperature = 0.140 NaCl = 0.374

Discussion:

The total alkali content of soap, as indicated by the results in figure 16, falls within a range of 0.04%-0.70%, which is within the range when compared with the data obtained in the reference study which ranges from 0.02%-0.62% with the same measurement methodology [41]. In another different method conducted by Idoko et al. [42], fifteen soap samples were examined,

revealing that eleven of them have total alkali content ranging from 0.06% to 0.22%. These values comply with the ISO standards, with a maximum allowable limit of 5% according to the ISO standard [BIS], and 2% according to the ISO specification [43]. This suggests that the soap is unlikely to be abrasive to the skin.

The analytical plot illustrates the influence of temperature and NaCl on the values of total alkalinity. It was observed that lower temperature as well as lower amounts of NaCl for salting out results in higher total alkalinity. The moderate value was observed in moderate temperature and NaCl. Lastly, the least value was observed in the highest temperature and the amount of NaCl used for salting out.

7.6 Foaming capacity

The bar chart below illustrates the values of the foaming capacity (%) of the 9 samples prepared in the laboratory. While the contour plot in Fig. 19 shows the foaming capacity on temperature and amount of NaCl.

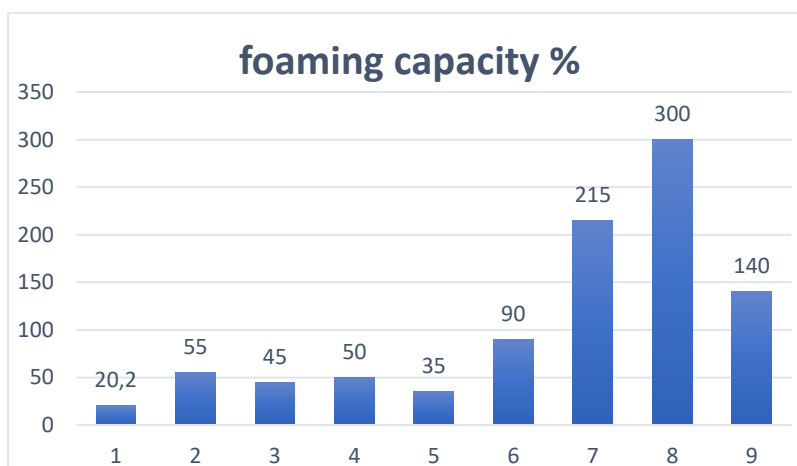


Figure 18. Bar chart comparing the foaming capacity of the soap samples

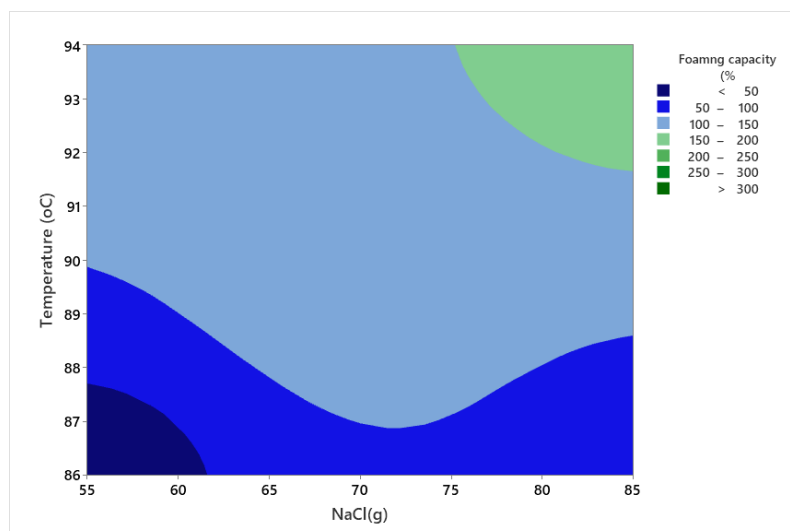


Figure 19: Graph of dependence of foaming capacity on Temperature and amount of NaCl

Regression equation:

$$\text{Foaming capacity (\%)} = -1680 + 12.81 \text{ Temp}(\text{°C}) + 1.50 \text{ NaCl} + 11.74 \text{ KOH}$$

$$P(\text{value}): \text{KOH(g)} = 0.047, \text{ Temperature (°C)} = 0.071, \text{ NaCl (g)} = 0.363$$

Discussion:

The laboratory produced soaps failed to match the foaming capabilities of commercially available ones. This discrepancy could stem from the absence of additives in the laboratory formulation known to enhance foaming and water softening. While my experiment utilized a different methodology for assessing lather compared to reference [43], their findings still showcased considerable lather, if not greater, owing to their distinct approach. In contrast, reference [44] employed a methodology like mine but with a different soap variant Sodium dihydroxy stearic acid soap and a more substantial liquid solution. Despite these differences, the dihydroxy stearic acid soap demonstrated marginally inferior foaming properties compared to the laboratory produced soaps. Notably, the experimental accuracy may have been compromised by inconsistent shaking due to the absence of suitable equipment in the laboratory, despite efforts to standardize the process with 20 repetitions for each measurement. From my soap samples produce sample 8 has the highest foaming capacity close to the study works from the reference. The foaming capacity of soap can be improved by adding additives such as honey or granulated sugar.

According to the analytical plot above, the temperature, and the amount used for

salting influence the foaming capacity of the soap. It can be deduced that the minimum foaming level was seen at minimal value of temperature as well as minimal amount of NaCl. The soap capacity increases as the temperature and amount of NaCl for salting out increases by 50% at moderate temperature and NaCl. The maximum value of foaming capacity being sample 8 was observed at maximum temperature and NaCl.

7.7 Foam stability

The bar chart below shows the comparison of the stability of foam for all the prepared samples.

While the contour plot shows the dependence of foam stability on temperature and amount of KOH

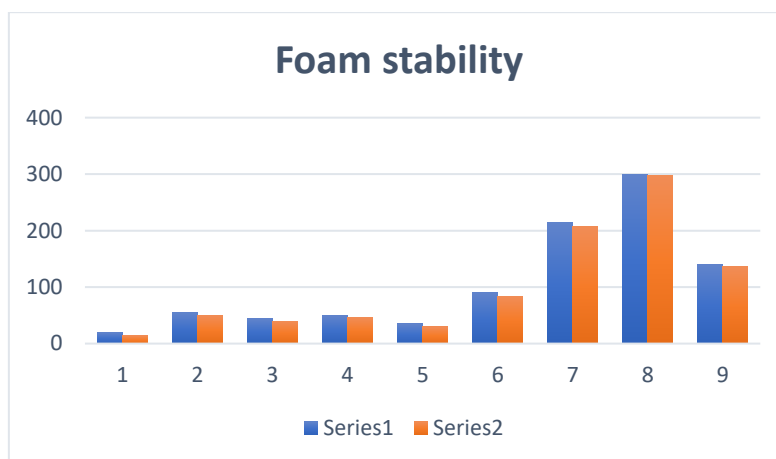


Figure 20: Bar chart illustrating the foam stability of the laboratory prepare soaps

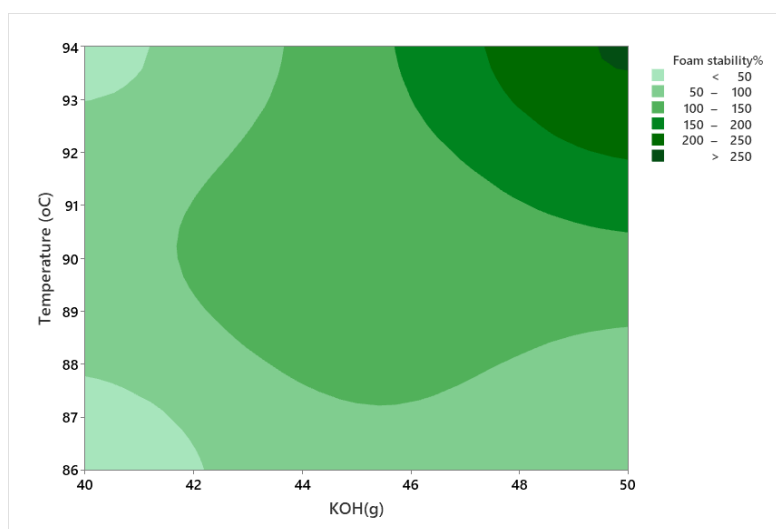


Figure 21: Graph of dependence of foam stability on Temperature and amount of KOH

Regression Equation

$$\text{Foam stability\%} = -1707 + 12.99 \text{ Temp (oC)} + 1.58 \text{ NaCl(g)} + 11.74 \text{ KOH(g)}$$

P(value): KOH = 0.047, Temperature = 0.068, NaCl = 0.338

Discussion:

The laboratory prepared soaps have slight decrease in its lathering, which ranges from 0.5-25% decrease in 30minutes, when comparing with the reference link for the sodium soap made from palm-based dihydroxystearic acid which up to 60% decrease in the soap lather volume [44]. The laboratory soap has better foam stability compared to soaps where more hydroxide than fat was used in their production according to reference [44]. The comparison between traditional soaps and those in the link is indeed not straightforward. The soaps in the link, crafted from a single type of fatty acid, possess distinct characteristics that differ from laboratory-made soaps comprised of a blend of fatty acids. These differences extend to the stability of the foam produced by the soaps, which can vary significantly between the two types.[26]

The analytical chart (figure 21) above illustrates the influence of temperature value and the amount of KOH used in saponification on the foam stability. A close study finds that at the minimal value of temperature as well as minimal amount KOH, the foam stability was low. Then was also observed that the stability of the soap was moderately increase as both parameters were increased. The highest foam stability was observed at the highest value of temperature and highest amount of KOH. [26]

7.8 Soap hardness (Penetration Test)

The penetration test is the parameter used to know the softest or hardest of a prepared soap. Fig.22 below is the bar chart comparing the penetration values of the laboratory prepared soap, while fig.23 is the contour plot showing the dependence of penetration on amount of NaCl and KOH

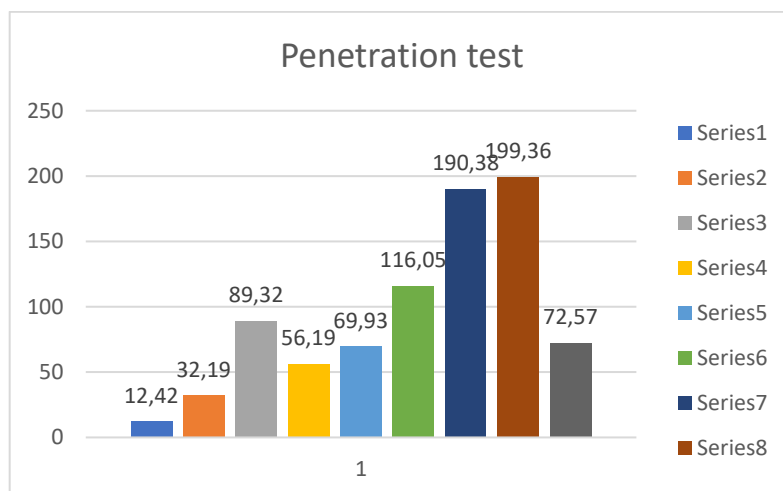


Figure 22: Bar chart illustrating the penetration values of the laboratory prepare soaps

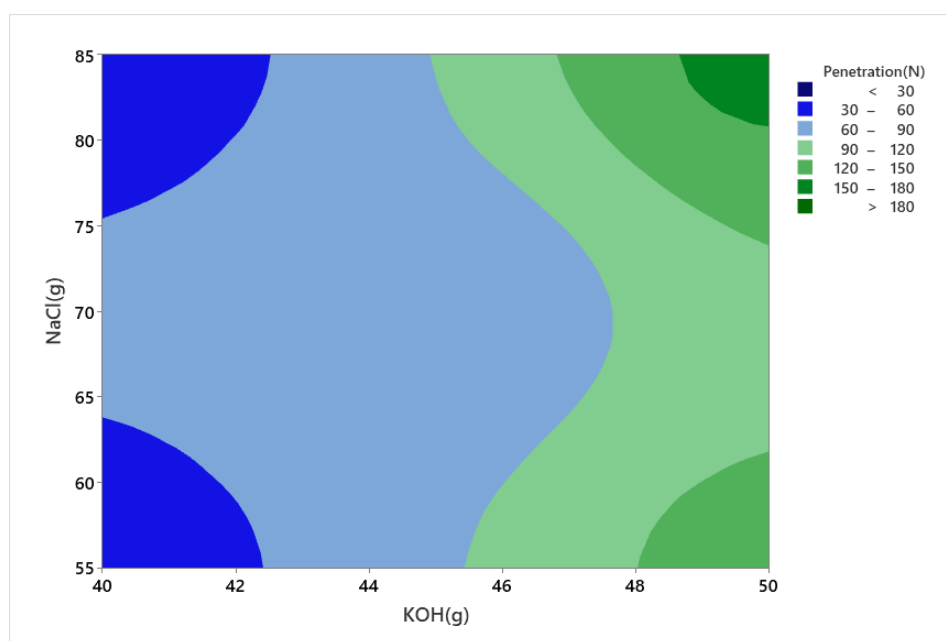


Figure 23: Graph of dependence of penetration on amount of NaCl and KOH

Regression equation

$$\text{Penetration (N)} = -1216 + 9.33 \text{ Temp}(\text{°C}) + 0.398\text{NaCl(g)} + 9.79\text{KOH(g)}$$

P(value): KOH = 0.003, Temperature = 0.009, NaCl = 0.541

Discussion

The softness or hardness of soap depends on the nature of the alkali used in their production. Sodium hydroxide (NaOH) will give rise to hard soap, whereas potassium

hydroxide (KOH) will form a soft soap. During the test process I observed that the soap samples broke when the probe was applied excluding samples 3,4,6 which didn't break. The highest force was observed in sample 8 followed by sample 7 while sample 1 has the least value. When compared with the that from the reference, the laboratory prepared soap was soft, the hardness of the soap can be enhanced with additives as well.

The hardness of soap according to the analytical chart in figure 23 shows the influence of amount of NaCl and KOH on the hardness. The softest soap was observed at the minimal value of NaCl and KOH. At moderate amount of the two parameters the hardness of the soap was increased by 30-60% while at the highest value of the two parameters the hardness of the soap was increased by 80-90% . when compared to the reference link, the laboratory prepared soaps were very soft.[37]. Though the softest of the soap doesn't affect the quality of the soap because the soap can be modified with additives to improve the hardness.

7.9 Total fatty matter

Total fatty matter is one of the parameters that is used to determine the quality of soaps. Fig.24 shows the bar chart comparison of the total fatty matter values for all the soap samples while fig.25 shows the contour plot shows the dependence of total fatty matter on temperature and amount of KOH

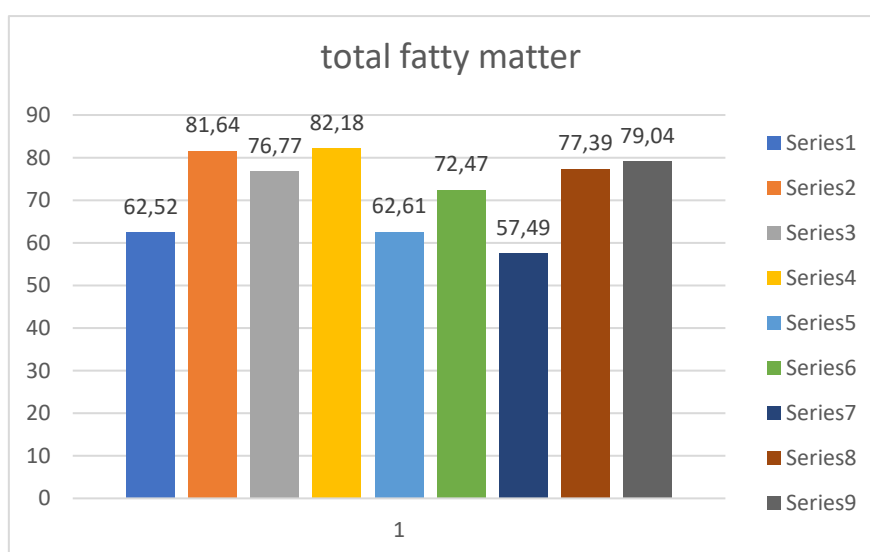


Figure 24: Bar chart illustrating the free fatty matter values of the prepare soaps

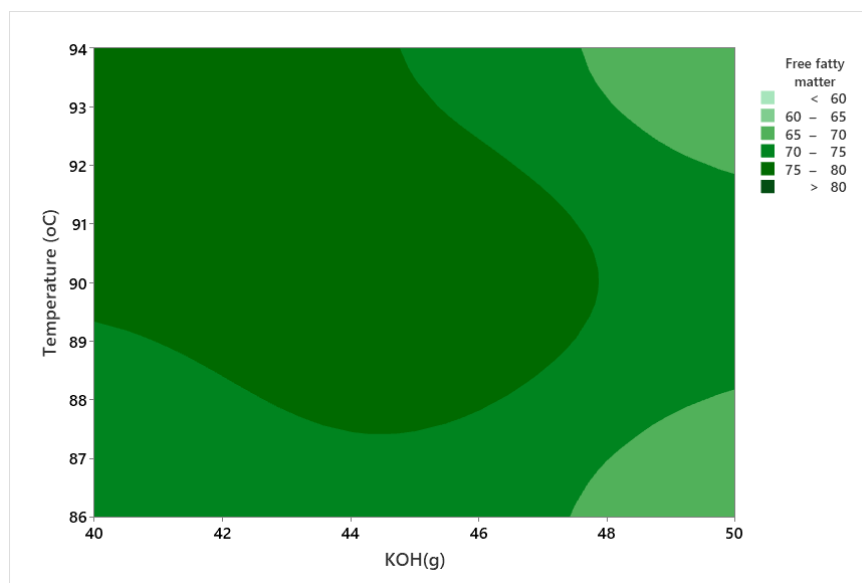


Figure 25: Graph of dependence of free fatty matter on temperature and amount of KOH

Regression equation

$$\text{Free fatty matter (\%)} = 37.0 + 0.456 \text{ Temp}(^{\circ}\text{C}) + 0.452\text{NaCl(g)} - 0.829\text{KOH(g)}$$

P(value): KOH = 0.087, Temperature = 0.393, NaCl = 0.018

Discussion

The total fatty matter is one important parameter that describes the quality of soap. The total fatty matter values of the results in Fig.24 ranged between 57-82%. According to ISO 685,76% is the acceptable total fatty matter. All the laboratory prepared soap falls without that value except sample 1, 5, and 7 with the values 62.5%,62.6% and 57.4 respectively that are lower, this is because of the presence of unreacted KOH during the saponification process.[42]

From the documentary reference [38], in their work with some toilet soaps it was observed that Septol with 26%, and Giv with 66% total fatty matter are lower, while Dudu Osun and Farhas' total fatty matter were 74 and 70% respectively, which according to ISO standard falls within the standard. This could be due to many additives such as fillers, preservatives, and color in the soaps to confer special properties to the soap [42] in essence the total fatty matter can be affected by the type of additives used in the soap processing. Soaps with a lower total fatty matter have low quality.

The analytical data in fig. 25 above illustrates the dependence of free fatty matter on temperature and the amount of KOH, the least value of free fatty was observed at low temperature with high amount of KOH as well as high temperature with high amount of KOH for a particular sample 7, indicating incomplete saponification i.e. there is presence of unreacted KOH. A favorable and high values of free fatty matter was observed at moderate temperature and moderate amount of KOH and when the two parameters are high.

7.10 Moisture content

Fig.26 shows the bar chart comparison of the moisture content for all the laboratory prepared soap, while fig.27 shows the contour graph of dependence of moisture content on temperature and amount of KOH

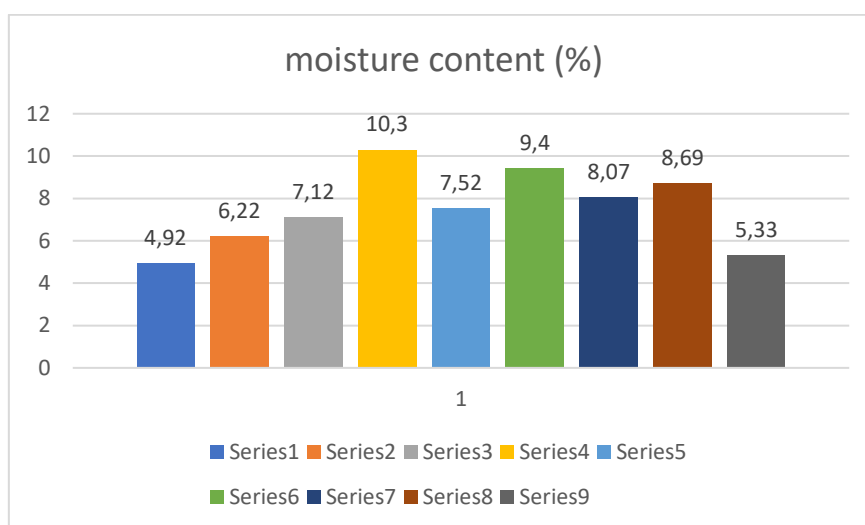


Figure 26: Bar chart illustrating the moisture content of the prepare soaps

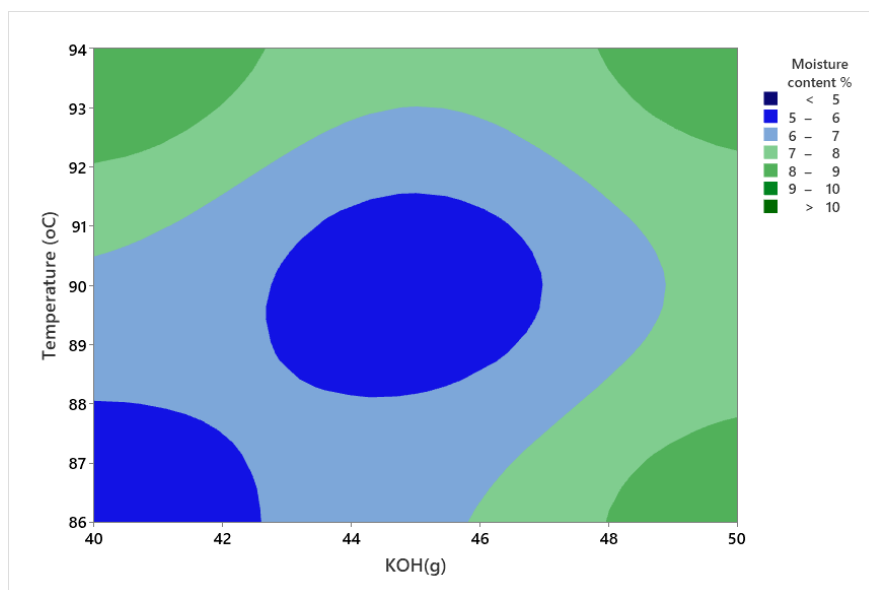


Figure 27: Graph of dependence of moisture content on temperature and amount of KOH
Regression equation

$$\text{Moisture content (\%)} = -19.5 + 0.191 \text{ Temp}(\text{°C}) + 0.0582\text{NaCl(g)} + 0.128\text{KOH(g)}$$

P(value): KOH = 0.300, Temperature = 0.226, NaCl = 0.176

Discussion

The bar chart in fig. 26 illustrates the moisture content of all the laboratory prepared soap. there is uneven in the result obtained considering the processing conditions used. The moisture content of soaps can be influenced by the duration the soap was prepared. The moisture content of the laboratory prepared soaps was low ranging from 4.92-10.30% when compared to the other study reported much higher moisture content that ranged from 24.90-43.24% [39]. The results found for some commercial soaps ranged from 30-35% [39]. In my own study lower moisture content could be explained by a different recipe and processing condition for soap preparation and not adding any substances or additives that helps in water retention to improve its moisturizing effect. Some best soap manufacturers declare a maximum of 14% moisture in their products [1]. The laboratory soaps fall within the range.

The plot in fig. 27 shows the dependence of moisture content on temperature and amount of KOH used in saponification, the minimal moisture content was recorded at minimal temperature as well as minimal amount of KOH and at moderate value of temperature and amount of KOH. The moisture content can be seen to have an increase 2-3times at the highest temperature and amount of KOH.

8. SUMMARIZING THE RESULT OF THE WORK

8.1 properties of the soap

The examination of the soap properties revealed that the pH levels of laboratory soaps, which range from 9.3 to 10.2, are within the range of most commercial soap, showing all the samples are in accordance with ISO standards. The assessment of total alkalinity demonstrated a comparable value with the study work done on the documentary reference link. The laboratory values range from 0.04-0.7 while that from the reference link ranges from 0.02-0.62 while another was from 0,06-0.22. All the laboratory soaps fall within the ISO standard of a maximum of 2%.

However, the foaming capabilities of the laboratory soaps fell short of those found in store-bought varieties and, in the documentary link, that ranged from 600- 800%. The laboratory soaps ranged from 20-300%, sample 8 being the highest. This disparity can be attributed to the absence of foaming enhancers in the laboratory formulations. Nevertheless, the laboratory soap exhibited better foam stability than the ones in the reference link.

Regarding hardness, laboratory soaps underwent a penetration test, resulting in cracking when molded into bar shapes except sample 3,4,6. Notably, Laboratory soap 8 emerged as the firmest, requiring 199.36N to fracture, while soap 1 proved the most pliable, recording merely 12.42N.

Subsequently, the total fatty matter of the laboratory soaps falls within the ISO 685 standards; 76% as the acceptable grade 1 value, except for soap 1,5, and 7 with the values 62.52%, 62.61% and 57.49% respectively that fall below the standard.

Finally, the moisture content of the laboratory ranged from 4.92-10.3% which falls within the ISO standard of maximum of 14%.

In summary, while the laboratory soaps demonstrated comparable pH, alkalinity, total fatty matter, and moisture content to their commercial counterparts, they lagged in foaming properties and exhibited varying degree of hardness, with some susceptibility to cracking during testing. In comparison with all the analyzed properties soap 8 comes out to be the best among the other samples. The foaming capacity of the soap can as well improve with the addition of additives like honey which is also good for the skin.

8. 2 Setting up optimal conditions for the preparation of soaps

In the ideal soap production setting, the aim is to ensure the full saponification of fats, yielding soap that is free from greasiness and discoloration. However, when working with fats containing impurities like residual meat tissue, precautions are necessary to prevent the soap from turning yellow during the maturation process.

I. Preparation

The pure deer fat, water and saponification solution should be in a ratio of 1:4:3. For proper saponification the saponification solution should contain 50% hydroxide by weight of the fat while the weight of salt should be 85% by weight of fat. The fat undergoes purification process if is not free of impurities (protein, blood, pieces of meat) before been transferred to saponification.

II. Fat purification

The weight of raw fat should be 2-3times the weight of the required pure fat for production. Place the fat in the beaker, then transfer to an oven and leave to dissolve at 130°C for 45-60mintues, after which the dissolved fat can be extracted with the aid of a metal sieve with a cloth sieve. For efficiency, ensure that the sieve cloth has a very tiny pore and wrap it up to 3-5times to ensure only the passage of the dissolved fat.

III. Saponification

After purification of the fat, add 400ml of distilled water to the pure fat (100g) and 15% by volume of the saponification solution, then place the mixture on an electric heating plate with a stirrer and heat up to the processing temperature (80°C) for 15 minutes with continuous stirring, subsequently add another 15% by volume of the saponification solution and maintain the processing temperature for another 15minutes. After that add 40% by volume of the saponification solution and then set the temperature to saponification temperature (94°C), and continue stirring for 25mintutes, finally add the remaining 30% of the saponification solution and stir for 75minutes, when the time elapsed off the electric heater while stirring for another 15minutes maintaining the processing temperature.

IV Desalination

Before salting commences, the mixture was top up with 500ml by volume of hot water (85°C)

which correspond to five times by weight of the fat sample. Still maintaining the processing temperature, add salt (sodium chloride) in teaspoon for an interval of 30seconds per teaspoon till all the amount of salt (85g). During this period the soap mixture could thicken, when the magnetic stirrer won't be able to stir the mixture, a glass rod can be used to ensure a homogenous mixture and stirred for 5minutes. As the time elapsed, remove the beaker from the heating plate and let to stand for 1hour without stirring, while standing the mixture separated into two layers: a mother liquor as the bottom layer while the top layer is the raw soap(cake). Filter the soap cake from the mother liquor with the aid of a separating funnel and sieve cloth. The pH of the mother liquor should as well recorded.

V Neutralization

After proper separation, neutralize the soap first with 500ml of chilled 1% acetic acid followed by 500ml of 0.5% chilled acetic acid. After neutralization, Transfer the soap into a pre-weighed silicon mold and then weigh it. Subsequently, place the moist soap in a drying oven with air circulation at a temperature of 30°C for 24hours, weigh the soap again, and place at room temperature for 14 days.

VI Finalization

After the ripening period, the soap can then be modified by adding additives such as dye, aroma, foaming enhancers to improve the quality as well as satisfying its application.

8. 3 Significance for science and practice

Processing waste fat into soap indeed presents a viable economic opportunity for the companies in the animal processing industry. By utilizing a relatively simple process, these companies can transform waste fat into a valuable raw material that can be sold to cosmetic companies for use in their products. This not only eliminates the need to pay for rendering plants for disposal but also generates additional revenue streams. The saponification process is a simple process and relatively straightforward process which involves mixing fat with potassium hydroxide and water and then heating the mixture to create soap stock. The process can be integrated into existing operations with minimal additional investment. Moreover, the cost savings are significant, purchasing potassium hydroxide in bulk reduces costs compared to paying rendering plants for waste disposal. Additionally, the ability to

produce soap internally reduces reliance on external vendors and ensures a stable supply of raw material for soap production.

Furthermore, selling soap to cosmetic companies allows animal processing companies to tap into new markets and diversify their revenue sources. As demand for natural and sustainable ingredients in cosmetic products continues to grow, soap stock derived from waste fat presents an attractive option for cosmetic manufacturers looking for eco-friendly alternatives.

Overall, the processing of waste fat into soap stock not only offers economic benefits for animal processing companies, but also contributes to environmental sustainability by reducing waste and promoting the circular economy.

8.4 Recommendations for further research

In further exploration of soap production from fat, emphasis should be placed on the production technology, particularly its relationship with temperature. Three distinct types of soap production, each correlated with temperature variations, would be examined to understand the resultant texture variations when produced at room temperature versus at 80°C.

To maintain continuity with the method outlined in the diploma thesis, it is suggested to concentrate on the quantity of KOH in the saponification solution, a critical component for saponification. Another avenue for investigation involves refining the ranges of KOH concentration, temperature, and NaCl for salting out, aiming to discern the specific properties of the resulting soaps. Additionally, the Evaluation of soap properties would primarily focus on penetration and hardness, with the recommendation to produce multiple samples for penetration testing to ensure accurate and reliable results without compromising sample integrity.

Subsequently, finalization is indeed a crucial step in soap manufacturing, especially if you're aiming to create a product that competes effectively in the commercial market. Research focused on this aspect could yield valuable insights into enhancing the quality and appeal of the final product.

CONCLUSION

The theoretical segment of the thesis comprises four sections. The initial section offers concise insights into fats and fatty acids, encompassing their physical attributes and composition, as well as the distribution and composition of fatty acids in fats sourced from both plant and animal origins. The second part focuses on the processing of animal fat, elaborating on the methodological aspects involved, followed by the subsequent refining of crude soybean oil. The third segment delves into the acquisition of fats from animal sources, while also delineating other animal tissues and organs rich in fats, alongside a comparative analysis of fatty acid compositions in fallow deer and domestic animals. Additionally, this section explores alternative applications of animal fats and oils beyond the realm of the food industry. The fourth section outlines various methods of soap production.

The practical component of the thesis revolves around the production of soap derived from deer fat. The primary objective here is to demonstrate the feasibility of creating soap from this fat source, aiming to achieve a quality comparable to commercially available soaps. Alongside the primary objective, the study also hypothesizes the soap production process, estimating the requisite quantities of KOH and NaCl and predicting the sensory and physical properties of the resulting soap. The methodology involves monitoring three key variables during the production of different soap samples: temperature (86°C, 90°C, 94°C), NaOH quantity (40g, 45g, 50g), and NaCl quantity (55g, 70g, 85g). Subsequent analyses are conducted on the produced samples to ascertain pH levels, total alkalinity, foaming capacity, foam stability, penetration, free fatty matter, and moisture content.

Lab-made soaps had pH values of 9.35 to 10.21, higher than store-bought soaps. The total alkalinity of the produced soaps reached values of 0.04 to 0.7. The foaming capacity of the laboratory soaps ranged from 20.2-300% of the spread. These values were low compared to the ones in the literature but can be enhanced with some additives. The moisture content falls within ISO standards, while the values of the penetration test shows that the soaps were soft.

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LIST OF ABBREVIATIONS

N	Newton
EEC	European Economics Community
ABPR	Animal By-Products Regulation
HACCP	Hazard Analysis and Critical Control
EFPPRA STG	European Fat Processors and Renderers Association - Scientific and Technical

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