FARM LEVEL STORAGE OF SUNFLOWER OIL

THESIS

Submitted to the Punjab Agricultural University
in partial fulfilment of the requirement
for the degree of

MASTER OF TECHNOLOGY

in

AGRICULTURAL ENGINEERING

(Agro Industrial Processing)

by

Pramod Kumar Raghav

(L-93-AE-158-M)

Department of Processing & Agricultural Structure

College of Agricultural Engineering

PUNJAB AGRICULTURAL UNIVERSITY

LUDHIANA-141004

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DEDICATED

TO MY

REVERED PARENTS

Title of Thesis	: Farm level storage of sunflower oil
Name of the student and admission number	Pramod Kumar Raghav : L-93-AE-158-M
Name of the Major Advisor and designation	: Prof. P.C. Grover Sr. Extension Specialist Dept. of Processing and Agricultural Structures
Major Subject	: Agro-Industrial Processing
Minor Subject	: Computer Science and Electrical Engineering
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ABSTRACT

Studies on storage of raw sunflower oil were carried out for domestic as well as farm level storage. The effect of different packaging materials, under various conditions on the keeping quality and storability of oil were evaluated. The packaging materials comprised of four different materials viz., plastic, tin, hindolium and plastic pouch and one each for non heated non airtight and nonheated airtight as well as heated non airtight and heated airtight. These replications for each packaging material were kept for study. For each packaging material the oil was stored as raw oil with and without heating. In case of heated oil the oil was heated in a stainless steel container at 120°C temperature for 90 minutes of duration in order to inactivate the enzymatic activity. Each container was of 2 kg capacity and pouches were of 100g capacity each for each replication.

It was found that different packaging materials and conditions effect the quality of oil. The airtight plastic pouches with heated oil were found as the best packaging material for sunflower oil storage from all the materials under study for storage period of 16 weeks.

26.2.96

Signature of Major Advisor
(Prof. P.C. Grover)

Signature of student
(Pramod Kumar Raghav)

CERTIFICATE I

This is to certify that this thesis entitled, **"Farm Level Storage of Sunflower Oil"** submitted for the degree of Master of Technology, in the subject of **Agro-Industrial Processing** (Minor: Computer Science and Electrical Engineering), of the Punjab Agricultural University, Ludhiana is a bonafide research work carried out by **Pramod Kumar Raghav** (L-93-AE-158-M) under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigations have been fully acknowledged.

26.2.96

(Prof.P.C. Grover)
Major Advisor
Senior Extension Specialist
Department of Processing and
Agricultural Structures
PAU, Ludhiana.

CERTIFICATE II

This is to certify that the thesis entitled, **"Farm Level Storage of Sunflower Oil"** submitted by **Pramod Kumar Raghav** (L-93-AE-158-M) to the Punjab Agricultural University, in partial fulfilment of the requirements for the degree of Master of Technology, in the subject of Agro-Industrial Processing (Minor: Computer Science and Electrical Engineering), has been approved by the student's advisory committee after an oral examination on the same, in collaboration with an external examiner.

(Prof. P.C. Grover)
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23/5/96

External Examiner
Dr. Jaswant Singh
(Project Coordinator)
IISR, Lucknow

(Dr. Rajinder Singh)
Head of the Department

(Dr. K.D. Mannan) 20/9/96
Dean, Postgraduate Studies

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Pramod Kumar Raghav

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LIST OF SYMBOLS AND ABBREVIATIONS

AOCS	American Oil Chemists Society
JOAOCS	Journal of American oil Chemists Society
ASAE	American Society of Agricultural Engineers
BIS	Bureau of Indian Standards
ISI	Indian Standard Institution
NHATP	Non heated air tight plastic
NHATT	Non heated air tight tin
NHATH	Non heated air tight hindolium
NHATPP	Non heated air tight plastic pouches
NHNATP	Non heated non air tight plastic
NHNATT	Non heated non air tight tin
NHNATH	Non heated non air tight hindolium
NHNATPP	Non heated non air tight plastic pouches
HATP	Heated air tight plastic
HATT	Heated air tight tin
HATH	Heated air tight hindolium
HATPP	Heated air tight plastic pouches
HNATP	Heated non air tight plastic
HNATT	Heated non air tight tin
HNATH	Heated non air tight hindolium
HNATPP	Heated non air tight plastic pouches
S.G.	Specific gravity
F.F.A.	Free fatty acid
I.V.	Iodine value
S.V.	Saponification value

A.V.	Acid value
Kg	Kilogram
gm	Gram
No	Number
Fig.	Figure
et al.	and others
°C	degree centigrade
R.H.	Relative humidity
viz.	vidilicet (that is)
pp.	Pages
PAU	Punjab Agricultural University
%	Per cent
cst	Centi stock

CHAPTER I

INTRODUCTION

India is the second largest country in Asia after China with regard to area under sunflower (4,94,89,000) ha as well as it's production (4,123,000) metric tonnes (Anonymous, 1991). Oil seed production is regarded as a sick segment of Indian Agriculture, India an exporter of oil seeds till 1965 is presently spending a lot of precious foreign exchange on importing edible oils. This happened because of the increase in population and it's purchasing power. The production of oil seeds in India during 1985-86 was 108.32 lakh metric tonnes and the population in 1981 census stood at 68.33 crores (India, 93), whereas in 1993-94 it was 214.18 lakh metric tonnes and the population had reached 91.25 crores (Anonymous, 1995). The inevitable effect of the population growth and increase in purchasing power has been that the oil seed production has fallen short of the requirement. Hence, heavy imports became necessary at the expense of huge foreign exchange. The import bill of edible oil in the country in 1993-94 was 167 crores (Anonymous, 1995). This is causing a great damage to the valuable foreign exchange resources of the country.

Realising the economic importance and keeping in

view the steadily widening gap between the domestic demand and supply situation of edible oils, the Govt. of India initiated several intensive oil seed development programmes as National Oil Seed Development Project (NODP, 1986), Technology Mission on Oil Seeds (TMO, 1986) and Oil Seed Production Thrust Project (OPTP, 1986). These two schemes NODP and OPTP were merged into a single scheme Oil Seeds Production Programme (OPP) during 1990-91. Likewise some schemes were undertaken by ICAR on the postharvest study of oil seeds. One such scheme Oil Seed Processing Network (1989) is going on at CIAE, Bhopal.

In the recent years the sunflower has become an important oil seed crop of Punjab. In 1986-87, it was grown on 900 hectares only with a production of 900 metric tonnes whereas in 1991-92 it was grown on 86,673 hectares with a total production of 130,000 metric tonnes. This is an increase of 9530.33 per cent in area and 16,150 per cent in the production. In 1993-94 season Punjab produced 165,000 metric tonnes of sunflower seed while the all India production was 580,000 metric tonnes. The total land area of Punjab is only 1.5 per cent of that of India but it contributes about 12.24 per cent of total sunflower production (DDA, 1994). Sunflower seed contains 40-42 per cent low cholesterol high quality of oil (Package of Practices for Crops of Punjab, Rabi 1993-94). That is why this oil is getting popularity with the manufacturers of edible grade refined oil and for vanaspati units. Lower

grade sunflower oil can be used for making soap and a number of allied products. Since this oil has low cholesterol and more unsaturated fatty acids (Swern, D. 1979) along with greater health awareness in the public, the sunflower has very bright future.

The sunflower oil is obtained by mechanical pressing or by solvent extraction of the seeds. The raw sunflower oil is mostly used by the farmers for edible purposes is found to be sensitive to deterioration (Sherwin and Luckadow, 1972). So, in order to obtain the oil throughout the year, farmer can store the sunflower as seed or he can get the whole crop expressed and store the oil. Getting oil from its seed by the farmers is also a value added product. But this oil if kept as raw has been found to deteriorate soon with pungent smell due to hydrolytic enzymes. Therefore, there is need to improve the shelf life of this sunflower oil to be kept at farm level by farmers for his own consumption or to be sold as the value added product at suitable price level. Keeping in view the above factors, this study was undertaken with the following objectives:

1. To study the storage behaviour of sunflower oil stored in different containers under aerated and nonaerated conditions.
2. To study the effect of heat treatment on sunflower oil under aerated and nonaerated conditions.

CHAPTER II

REVIEW OF LITERATURE

This chapter gives an overview of the work already done by various research workers on the storability of different oils with particular reference to sunflower oil. In this chapter efforts have been made to review the various physical properties and qualitative characteristics of the oils under different headings as follows:

2.1 Definitions

2.2 Characteristics of sunflower seed

2.3 Characteristics of sunflower oil

2.4 Oxidation

2.5 Physical properties

2.5.1 Specific gravity

2.5.2 Colour

2.5.3 Odour

2.6 Biochemical properties

2.6.1 Free Fatty Acid/Acid value

2.6.2 Iodine number

2.7 Requirements and specifications for sunflower oil

2.1 Definitions

a) Specific gravity

It is defined as the ratio of the weight of a unit volume of the sample to the weight of a unit volume of water at 25-40°C.

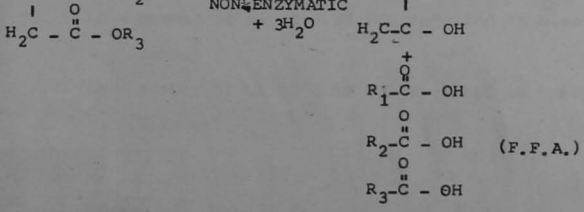
$$\text{Specific gravity at } 25°C = \frac{\text{Wt. of bottle \& sample - Wt. of bottle}}{\text{Wt. of water at } 25°C}$$

b) Acid value

The acid value is defined as the number of milligrams of KoH required to neutralise the free fatty acids in 1 gm of the oil.

c) Free fatty acid:

Formula:- the fatty acids released from fat (oil) molecule during storage due to enzymatic or nonenzymatic reactions are defined as free fatty acids since these fatty acids are separated from glycerol of the fat as given in the following formula:



d) Iodine value:

The iodine value is defined as the number of grams of iodine absorbed per 100 gm of the oil.

$$IV = \frac{(X-Y)\ I.100}{W}$$

Where;

X = volume of 0.1N sodium thiosulphate solution in ml, required for blank test

Y = Volume of 0.1N sodium thiosulphate solution in ml, required for test with oil.

I = Weight in grams of iodine equivalent to 1 ml of sodium thiosulphate solution (126.6) - a standard value.

e) Saponification value:

It is defined as the number of milligrams of potassium hydroxide which is required to saponify 1 gm of the oil.

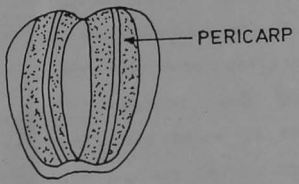
$$SV = \frac{(A-B)\ (28.05)}{W}$$

where:

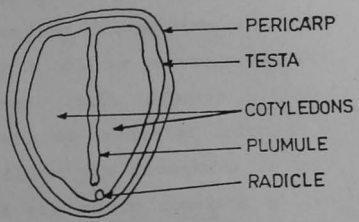
W = Weight of the oil sample in gms

A = Number of ml of 0.5N HCL required in blank test.

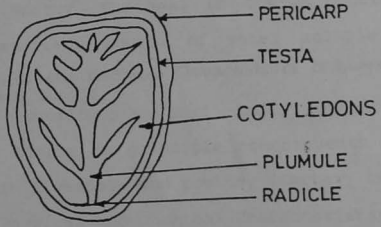
B = Number of ml of 0.5N HCL required in test with oil.



a) EXTERNAL VIEW



b) L.S. AT RIGHT ANGLE



L.S. PARALLEL TO FLAT SURFACE

L.S. LONGITUDIONAL SECTION

Fig. 2.1. STRUCTURE OF SUNFLOWER (Helianthus annus) SEED

2.2 Characteristics of Sunflower Seed and Hull

The sunflower seed is more correctly described as an acne (intact seed) of the plant Halianthus annus (Carter, 1978). It is pointed at the base, rounded at the top and approximately 10-15 mm long, 4-5 mm wide and 1-2 mm thick. The outer portion of the hull or pericorp consists of elongated and pigmented cells (Carter, 1978). Immediately below is the testa or seed coat which is a white peppery layer. In sunflower the endosperms is only one or two cells thick and the embryo consists of two cotyledons. The main exceptions are the higher fiber content and ash content, which tend to reduce the metabolizable energy. The meal is a high protein product and is an excellent source of water soluble B-complex vitamins. Physical and chemical characteristics of sunflower seed are given in table 2.2

The sunflower's seed hull contains lipids, cellulose and lignin as principle constituents and can be used as feed in livestock and poultry (Carter, 1978). given in table 2.2

Table 2.1 Physical and Chemical Characteristics of Sunflower Seed (Helianthus annus)

1000 seed weight (gm)	500ml weight (gm)	Bulk density (gm/cc)	Hull %	Oil %	Protein %	ETOH soluble extract %	Fiber resi-due %	Ash %
50.2	218.3	0.436	24.8	48.9	13.8	7.5	27.1	2.7

Source : Carter, J.F. 1978

Table 2.2 Composition of sunflower seed hull

Product	Fat %	Cellulose %	Protein %
Hull	5.4	47.1	7.3

Source: Carter, J.F. 1978.

2.3 Characteristics of Sunflower Oil

In the crude form, the colour of sunflower oil is light amber and that of the refined oil is pale yellow similar to that of many other vegetable oils. The crude oil contains some phospholipids and miscellaneous matter but less than cotton seed oil. Its free fatty acid composition is similar to that of most other vegetable seed oils.

The distribution of its fatty acid in the oil is given in table 2.3.

As shown in the table, the oil is found to be better for cooking purposes due to its high percentage of unsaturated fatty acids (essential fatty acids. Sunflower seed oil has a distinctive pleasant odour which can be completely removed by steam deodorization. (Campbell, E.J. 1983)

Table 2.3 Fatty Acid Distribution for Sunflower Oil

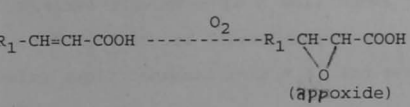
Fatty acids	United States	Argentinean	Range of values	GLC
Saturated				
Palmitic	3.6	6.4	3-6	11
Stearic	2.9	1.3	1-3	6
Arachidic	0.6	4.0	0.6-4	-
Behinic	-	0.8	0-0.8	-
Lignoceric	0.4	-	0-0.4	-
Total saturated	7.5	12.5	8.7-14.2	17
Unsaturated				
Oleic	34.0	21.3	14-43	29
Linoleic	57.5	66.2	44-75	52
Total unsaturated	91.5	87.5	85-91	83[a]

a - includes 2% linolenic acid.

Source : Swern Daniel, 1979

2.4 Oxidation

Vegetable oils or lipids are subjected to oxidation upon standing in the atmosphere during storage. Lipids are mostly triglycerides, esters of fatty acids and glycerols. Lipase is the enzyme which hydrolyse this ester bond with the result free fatty acids are released. These free fatty acids with the combination of oxygen present in the air form a appoxide as:



This reaction takes place in the stored oil even in absence of any enzyme. This chemical structure causes the oil to be rancid and renders it unfit for human consumption since this structure is undesirable by the body. The fatty acids in vegetable oils are mainly unsaturated fatty acids, having double bond which are prone to peroxide formation. These appoxides are injurious to health (Todd et al 1968)

Robertson (1972), stated that oxygenated fatty acids which have been identified in sunflower oil may have an adverse effect on its oxidative stability.

Luckadow and Sherwin (1972) reported that crude sunflower oil is very susceptible to oxidation thus

prolonged storage should be avoided.

Bhatnagar and Singh (1972), stated that storage of any oil results in deterioration due to oxidation.

Pillayer (1978) stated that the method of inactivating the lipase enzyme holds promise as a safe method for use and has been tried earlier and found suitable

Singh et. al. (1979) stated that the rapid rise of F.F.A. in freshly obtained rice bran is a well known phenomenon. It is due to the activity of lipase enzyme which hydrolyse the oil causing rapid increase in F.F.A. and rendering the oil non-edible.

Swern (1974) also reported that the prolonged storage of any fatty oil is undesirable because of deterioration that occurs through oxidation.

Hung et al. (1981), found out that the stability of the corn oil is same as that of sunflower oil.

2.5 Physical Properties

2.5.1 Specific Gravity

Formula:

$$\text{Specific gravity at } 25°C/25°C = \frac{\text{Wt. of bottle \& sample - Wt. of bottle}}{\text{Wt. of water at } 25°C}$$

2.5.2 Colour Number/Index:

Lamb and Sreerangachar (1965) firmly established that peroxidase did not take part in the oxidation of polyphenols during fermentation. Thus it seemsthat in the nonenzymatic breakdown, peroxides generated from other substrates can directly react with anthocyanin, causing a loss in colour. The nonenzymatic loss of colour in anthocyanin containing tissues can occur in either the presence or absence of oxygen.

Bhatnagar and Singh (1972) stated that the colour stability of the stored vegetable oils is changed due to its oxidation. They found that the colour of oil stored in iron tanks became darker as compared to others.

Carter (1978) concluded that the presence of iron derivatives darkens the colour of oil because of increase in the oxypolymers concentration.

Subrahmanyam V.V.R. (1979), found that the colour development accelerated during storage of expressed crude oil, as compared to seed oil, if stored as seed.

Handoo et al. (1992) studied the quality characteristics and shelf life of groundnut oil-mustard oil blend and sunflower oil-mustard oil blend. They found that the fall in colour value was fast in case of sunflower oil-mustard oil blend.

Handoo et al. (1992) found a fall in colour value of groundnut and cotton-seed oils on storage in PET, PVC

and HDPE containers for 6 months. However, a significant rise in colour value was observed in case of heated (180°C) oils.

2.5.3 Odour

Carter (1978) reported that the presence of iron derivatives deteriorate the flavour of oil because of increase in oxypolymer concentration.

Campbell (1983) stated that sunflower oil has a very distinctive odour which is neither unpleasant nor offensive.

2.6 Biochemical Properties

2.6.1 Free fatty Acid/Acid value

Singh et al. (1979) stated that the rapid rise of F.F.A. in the freshly obtained rice bran is due to the activity of lipase enzymes which hydrolyse the oil thus rendering the oil nonedible due to high percentage of F.F.A. in oil.

Bhatia and Roy (1972) found that the acid value of raw, filtered and refined groundnut, coconut and cotton seed oils increased with the storage period.

Nasirullah and Nagaraja (1989) conducted studies for refined sunflower oil under ambient conditions of temperature (18-32°C) in brown colour and colourless bottles.It was observed that the F.F.A. of stored sunflower oil changed from 0.15 to 0.53 on coloured bottles and from 0.15 to 0.60

in colourless bottles, showing that light has some effect on F.F.A..

Nakpa et al. (1990), stored crude palm oil in metal cans, green glass bottles, amber glass bottles and plastic bottles in direct sunlight at temperature of 40±1°C and in dark at temperature of 27±1°C for 98 days. It was observed that the rapid rise in F.F.A. was more in oils where the bottles were placed in direct sunlight.

Handoo et al. (1992) studied the quality characteristics and shelf life of groundnut oil-mustard oil blend and sunflower oil-mustard oil blend. It was found that the F.F.A. increased gradually in both the blends.

Handoo et al. (1992), found a steady rise in F.F.A. of groundnut and cotton seed oils stored in PET, PVC and HDPE containers for six months.

Palaveeva et al. (1993) studied the quality of crude sunflower oil stored for 1,2 and 3 month and compared with quality of refined sunflower oil stored for 3 months.

Unlike refined sunflower oil quality of crude sunflower oil rapidly deteriorated to a point where it no longer met quality standards.In order to maintain quality it was recommended that crude oil be stored for a maximum period of one month prior to refining.

2.6.2 Iodine Number/Value

Iodine value refers to the unsaturation of fatty

acids that are released by lipase enzyme. Less the iodine value less is the unsaturation and deterioration of quality.

Handoo et al. (1992) studied the quality characteristics and shelf life of groundnut oil-mustard oil blend and sunflower oil-mustard oil blend. A steady fall in iodine value was observed in both the cases.

Handoo et al. (1992) established that a direct fall occurs in iodine value of groundnut and cotton seed oils on storage in PET, PVC and HDPE containers for 6 months. However, a significant fall in iodine value was observed in case of heated oil (180°C).

2.7 Requirements and Quality Specifications for Sunflower Oil

2.7.1 Requirements (BIS: 4277-1975)

(i) The material shall be obtained from good quality sunflower seed cake or from undamaged, mature sunflower seed from Helianthus annus Linn. fam.

(ii) The material shall be clear and free from adulterants, sediments, suspended and other foreign matter, separated water, and added colouring and flavouring substances.

(iii) The material shall also comply with the requirements given in IS:4277-1975 of table 2.4

Table 2.4 IS:4277-1975 Specifications for Sunflower Oil

Characteristics	Requirement for type				
	Expressed		Solvent extracted		
	Raw	Refined	Raw	S.Refined	.Refined
1. Moisture and insoluble impurities (% by mass)	0.25	0.1	0.5	0.25	0.1
2. Colour	20	5	25	10	5
3. Refractive index at 4°C	------ 1.464 to 1.480 ------				
4. Saponification value	-------- 188 to 194 ------				
5. Iodine value	------- 100 to 140 -------				
6. Acid value	3.0	0.5	5.0	0.75	0.5
7. Unsaponifiable matter (per cent by mass)	1.5	1.5	2.0	1.5	1.5
8. Flash point (°C)	-	-	100	125	250

2.7.2 Specifications for Sunflower Oil According to AOCS

The AOCS specifications for sunflower oil is given below in Table 2.5.

Table 2.5 AOAC specifications for sunflower

S.No.	Property	Value
1.	Specific gravity (25-40°C)	0.915 - 0.920
2.	Refractive index (25°C)	1.472 - 1.474
3	Iodine value	125 - 136
4	Unsaponifiable matter	≯ 1.5%
5	Acid value	2.76
6	Kinematic viscosity	3.31 cst

Main Inferences from Review

1. The storage life of oils depends upon the type of container, storage temperature and composition of oils etc.
2. Permeability of 0_2 to the oil is a very important factor during storage of oils.
3. Aluminium, tinned iron or stainless steel containers are well suited for almost all types of edible oils.

4. Increase in F.F.A. during oil storage is due to activity of lipase enzyme.

5. Colour darkens and flavour deteriorates during oil storage.

However, iodine value falls during storage.

CHAPTER III

MATERIAL AND METHODS

3.1 Materials under study:

Crop:- Sunflower (Rabi crop)

Botanical name: Helianthus annus Linn. family

Oil: Expressed sunflower oil

Environmental conditions:- Ambient

Period of study:- June 95 to October 95.

3.2 Parameters studied:

A. Physical Parameters

i) Specific gravity

ii) Colour

iii) Odour

B. Biochemical parameters

i) Free fatty acid/Acid value

ii) Iodine number/value

iii) Saponification number/value

Fig.3.1 A View of Packaging Materials (Non Heated oil) Under Study

3.3 Variables for study

A. Storage materials

i) Plastic containers

ii) Tin containers

iii) Hindolium containers

iv) Plastic pouches

B. Storage conditions

i) Aerated

ii) Non aerated

C. Treatments

i) Raw

ii) Heated treated

For heat treatment, the oil was heated up to 120°C for 90 minutes duration to inactivate the enzymes.

3.4 Measurement of Parameters

The measurement techniques for various parameters are given below.

3.4.1 Physical Parameters:

3.4.1.1 Specific Gravity:

The specific gravity was determined by A.O.C.S. official method (L 10a-57).

A. Apparatus used:

a) Specific gravity bottles with well fitting glass joints.

Fig.3.2 A View of Packaging Materials (Heated Oil) Under Study

b) Water baths maintained at 25±0.2°C)

c) Thermometer (0-100°c)

B. Procedure:

The specific gravity bottle was filled with oil to overflowing and it was held in its side such as to prevent the entrapment of air bubbles. After inserting the stopper, the bottle was held in water bath at 25±0.2°C for 30 minutes and then it was wiped off carefully in order to dry thoroughly. The bottle and contents were weighed and the specific gravity was calculated as below.

C. Calculation

Specific gravity at 25±0.2°C

$$\frac{\text{Weight of bottle + sample - weight of bottle}}{\text{Weight of water at 25°C(0.998 g/cc x V)}}$$

The values of specific gravity so obtained are given in Table A-I of Appendix A and summed up in table 4.1 and plotted in Figs. 4.1 and 4.2 of Chapter IV (Results and Discussion).

3.4.1.2 Colour:

The colour was determined by AOCS tentative method (^{C}c 13C-50)

A. Apparatus used:

Spectrophotometer

B. Reagents:

a) Carbon tetrachloride (ccl_4)

b) Nickel sulphate ($NiSO_4$)

c) AOCS official diatomaceous earth (bleaching earth).

C. Calibration of Spectrophotometer:

a) The spectrophotometer was turned on and allowed to warm up for 20 minutes before taking the measurements.

b) After this both the control knobs were rotated to the stop position.

c) Wavelength dial was set at 460 nm. Zero reading was rechecked and a cuvette filled with ccl_4 was inserted in the apparatus in order to set 100 per cent transmittance point exactly.

d) Further the cuvette was filled with $NiSO_4$ solution and was inserted in the apparatus to read the transmittance of the solution. The reading was between 24.2 and 28.2% as required.

e) Similarly, the instrument was set at 550 nm of wavelength and reading was taken for $NiSO_4$ solution. It was well within the range of 53.8 and 55.8% as required.

f) Similarly the instrument was set at 620 nm and 670 nm respectively also and reading was taken for $NiSO_4$ solution. These were also well within the range of 5.22 and 5.17, 1.10 and 1.09 respectively as required.

D. Procedure:

The oil sample was first treated with the

Fig.3.3 Spectrophotometer

bleaching earth and then it was agitated vigorously for 2-3 minutes at room temperature. Then it was filtered and the filtered oil was filled in the cuvette and a full column in the light beam was insured. Filled cuvette was placed in the instrument and absorbance was read to the nearest at 0.001 division at 460, 550, 620 and 670 nm of wavelengths.

E. Calculations:

The colour index/value was calculated by the formula:

Photometric colour

$= 1.29\ A_{460} + 69.7\ A_{550} + 41.2\ A_{620} - 56.4\ A_{670}$

Where A is the absorbance.

The values of colour number so obtained are given in Table A-2 of Appendix A and summed up in Table 4.2 and plotted in Figs. 4.3 and 4.4 of Chapter IV (Results and Discussion). Fig.4.5 and 4.6 show the colour developed in various containers under different conditions at the end of storage study.

3.4.1.3 Odour

Odour was measured by making a test panel of three persons selected at random and 5 points were given by each person for positive result and 0 points for negative result, thus a score was determined for each sample. The proforma used for this purpose is given in Table A-3a of Appendix A.

Calculations:

The odour number was then calculated as:

$$O = \frac{O_1 + O_2 + O_3}{3}$$

The values of odour so obtained are given in Table A-3 of Appendix A and summed up in Table 4.3 and plotted in Figs. 4.7 and 4.8 of Chapter IV (Results and Discussion).

3.4.2 Biochemical Parameters:

3.4.2.1 Free fatty Acid/Acid Value:

Free fatty acid was determined by AOCS official method (L_{3a}-57).

A. Reagents used:

a) Accurately standardized 0.025N NaOH solution.

b) Phenolphthalein indicator solution 1 per cent in 95 per cent.

c) Ethyl alcohol (95 per cent pure)

B. Procedure:

5g of oil was weighed accurately in a 500 ml flask and 75 to 100 ml of hot neutral alcohol was added in it. The mixture was agitated and heated in order to bring the free fatty acids into complete solution.

This was titrated while shaking with 0.025N, NaOH, using phenolphthalein as indicator to the first pink colour which persists for 30 seconds.

Fig.3.4 A View of F.F.A. Test in Progress

C. Calculations:

Calculations of free fatty acid were then made as

$$\text{Free fatty acid} = \frac{v\ N\ M}{10\ W}$$

Where: v = Volume of alkali used (in ml)

N = Normality of alkali used (0.025N)

M = Molecular weight of oleic acid predominating (282)

W = Weight of oil taken (5g)

The values of F.F.A. so obtained are given in Table A-4 of Appendix A and summed up in Table 4.4 and plotted in Figs. 4.9 and 4.10 of Chapter IV (Results and Discussion).

3.4.2.1a Acid Value:

The acid values were calculated on the basis of sulfuric acid. The amount of alkali used during the titration in F.F.A. estimation was taken as the base readings for calculations of acid values. These values are given in Table A-5 of Appendix A and summed up in Table 4.5 and plotted in Figs. 4.11 and 4.12 of Chapter IV (Results and Discussion).

3.4.2.2 Iodine Value:

The Iodine value was determined by AOCS official method (Ka 9-51).

A. Reagents used:

a) Carbon tetrachloride (CCl_4)

b) Potassium iodide KI (10 per cent solution)

c) Accurately standardized 0.1N solution of sodium thiosulphate

d) Glacial acetic acid of good quality

e) Wij's solution

f) Soluble starch solution (1 per cent).

B. Procedure:

2g of oil was weighed in a clean dry bottle of 500 ml. Then 10 ml of carbon tetrachloride and 20 ml of Wij's solution were added to it. The bottle was closed and left for half an hour. Then 15 ml of 10 per cent potassium iodide solution was added into it. To this 100 ml of water was also added and well mixed.

The contents were titrated with 0.1N sodium thiosulphate solution using starch solution towards the end of the titration as indicator. Further a blank test was carried upon the same quantities of reagents omitting the oil, at same temperature.

C. Calculations:

Iodide values were then calculated using the following equation:

$$\text{Iodine value (I.V.)} = \frac{(x-y)\,.\,I.100}{W}$$

Where:

x = Volume of 0.1N sodium thiosulphate solution in ml, required for blank test.

y = Volume of 0.1N sodium thiosulphate solution in ml, required for test with oil.

W = Weight of the oil sample taken in gms (2g)

I = Weight in grams of iodine equivalent to 1 ml of sodium thiosulphate solution (126.6)

The iodine values so obtained are given in Table A-6 of Appendix A and summed up in Table 4.6 and Figs. 4.13 and 4.14 of Chapter IV (Results and Discussion).

3.4.2.3 Saponification Value:

The saponification value was determined according to the AOCS tentative method (Ka 8-48).

A. Reagents used:

a) Accurately standardized, 0.5N HCl.

b) Alcoholic potassium hydroxide solution.

c) Phenolphthalein solution, 1 per cent in alcohol (95 per cent v/v).

B. Procedure:

A sample of 2 g of oil was taken in a 250 ml flask. Then 250 ml of alcoholic KoH was added to it. Same contents were taken in another flask. Both the flasks were connected to reflux condensers and heated in a boiling water bath kept at temperature of 100°C for 30 minutes. The flasks were continuously shaken while heating. After this

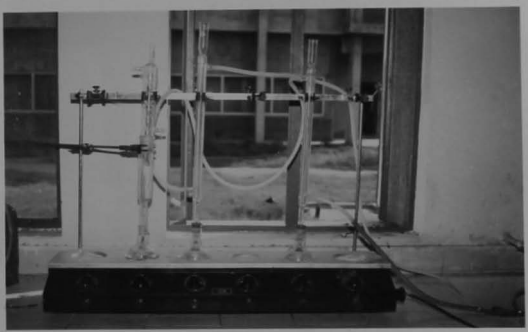


Fig.3.5 A View of Saponification Value Test in Progress

the flasks were removed and the contents were titrated with 0.5N HCl while they were hot, using phenolphthalein as indicator towards the end of titration. Pink colour was the end point.

Same procedure was followed for same quantity of reagents omitting the oil for blank test.

C. Calculations:

$$\text{Saponification value (S.V.)} = \frac{(A-B)\ (28.05)}{W}$$

Where:

W = Weight of the oil sample (2g)

A = Number of ml of hydrochloric acid required in blank test.

B = Number of ml of hydrochloric acid required in test with oil.

The saponification values so obtained are given in Table A-7 of Appendix A and summed up in Table 4.7 and plotted in Figs. 4.15 and 4.16 of Chapter IV (Results and Discussion)

3.5 Weather Data

The weather data viz. maximum and minimum temperatures and maximum and minimum relative humidity for the period of study were also recorded and are given in Table B-1 of Appendix B.

CHAPTER IV

RESULTS AND DISCUSSION

Sunflower oil stored in different packaging materials was kept in the Quality Control laboratory of the Department of Processing and Agricultural Structures, PAU, Ludhiana, for 3 months and 11 days (26th June to 16th October, 1995) under room conditions. Six different quality parameters both physical and biochemical viz. Specific Gravity, Colour, Odour, Free Fatty Acid content (F.F.A.), Iodine value (I.V.) and Saponification value (S.V.) respectively were selected for the study. The oil samples from each packaging materials were tested at an interval of one week. The packaging materials comprised of four different materials plastic, tin, hindolium and plastic pouch and one each for non-heated non airtight and non-heated airtight as well as heated airtight. Three replications for each packaging material were kept for the study. For each packaging material, the oil was stored as crude oil with and without heating. In case of heated oil the oil was heated in a stainless steel container at 120°C temperature for 90 minutes of duration to inactivate the

enzymatic activity. Each container was of 2 kg capacity and pouches were of 100 g capacity each. The results so obtained are presented as follows:

4.1 Physical Parameters

4.1.1 Effect on specific gravity (S.G.)

4.1.2 Effect on colour

4.1.3 Effect on odour.

4.2 Biochemical Parameters

4.2.1 Effect on free fatty acid content/acid value

4.2.2 Effect on iodine value (I.V.)

4.2.3 Effect on saponification value (S.V.).

4.1 Physical Parameters

4.1.1 Effect on specific gravity

The specific gravity of sunflower oil stored in different packaging materials for each heated and non-heated oil is presented in Table 4.1 and plotted in Figs. 4.1 and 4.2 respectively.

The data presented in the table and in the figures of nonheated and heated oil under non-air tight and air tight storage structures does not have much effect (of storage period) on specific gravity during the storage period under study. The values remained almost same during this storage period.

TABLE 4.1: VARIATIONS IN SPECIFIC GRAVITY OF SUNFLOWER OIL WITH STORAGE PERIOD

Containers	Treatments	Storage Period (Weeks)										
		0	1	2	3	4	6	8	10	12	14	16
A.T.P.	NH	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
	H	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
A.T.T.	NH	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
	H	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
A.T.H.	NH	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
	H	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
A.T.P.P.	NH	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
	H	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.A.T.P.	NH	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
	H	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.A.T.T.	NH	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
	H	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.A.T.H.	NH	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
	H	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.A.T.P.P.	NH	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
	H	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901

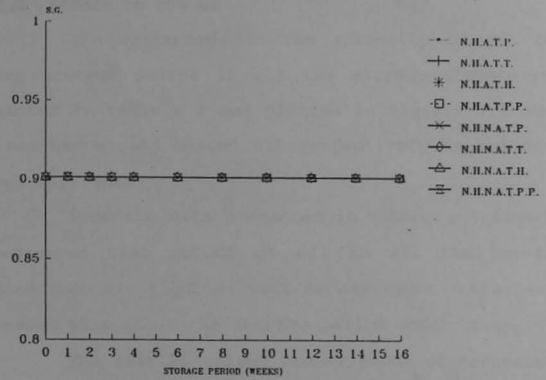


FIG 4.1. VARIATIONS IN S.G. OF NON HEATED SUNFLOWER OIL

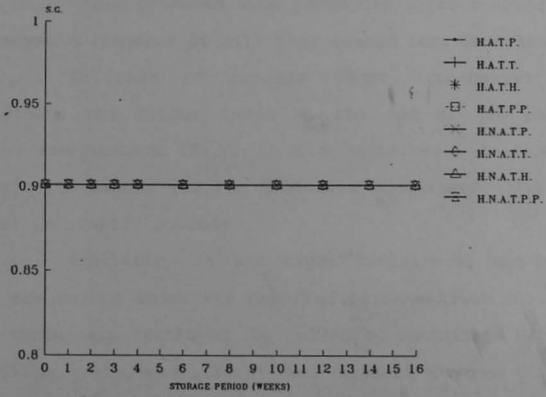


FIG 4.2 VARIATIONS IN S.G. OF HEATED SUNFLOWER OIL

4.1.2 Effect on colour

The variations in the intensity of oil colour during storage period in all the storage structures are presented in table 4.2 and plotted in figures 4.3 and 4.4 for non-heated and heated oil respectively in the form of colour No./index.

From the data presented in tables and figures it is observed that colour of oil in all the non-heated samples (not air tight as well as air tight containers) increased throughout the storage period under study.

The initial colour number/index of nonheated oil was 9.49 and that of heated oil was 6.42. The fall in initial colour number/index is because of heating of oil, that might have produced some peroxides which reacted with anthocyanin (pigment of oil) that caused loss in colour.

In case of non-air tight (non-heated oil) containers the colour index at the end of the storage period was maximum (22.7) in tin containers, followed by plastic containers (21.5), hindolium containers (20.9) and (20.0) in plastic pouches.

Similarly, in air tight containers (non-heated oil) the colour index was observed to be maximum (21.3) in tin containers followed by plastic containers (20.8), hindolium containers (20.7) and plastic pouches (20.6). Similar results were earlier reported by Subrahmanyam et al. (1979) in case of crude cotton seed oil storage.

TABLE 4.2: VARIATIONS IN COLOUR NUMBER/INDEX OF SUNFLOWER OIL WITH STORAGE PERIOD

Containers	Treatments	Storage Period (Weeks)										
		0	1	2	3	4	6	8	10	12	14	16
A.T.P.	NH	9.49	9.49	9.62	10.30	10.70	11.60	13.00	14.10	15.50	17.70	20.80
	H	6.42	6.47	6.88	6.94	7.79	7.81	7.79	6.96	6.19	4.51	4.51
A.T.T.	NH	9.49	9.49	10.00	10.40	11.40	12.40	13.9	15.30	17.10	19.10	21.30
	H	6.42	6.47	7.04	7.53	8.22	9.76	9.80	9.20	9.14	6.88	6.88
A.T.H.	NH	9.49	9.49	9.62	10.20	10.60	12.00	13.30	15.20	16.70	18.40	20.70
	H	6.42	6.47	6.55	6.91	7.17	8.24	8.24	8.17	7.70	5.47	5.47
A.T.P.P.	NH	9.49	9.49	9.59	10.00	10.40	10.80	12.10	13.70	14.60	16.10	20.60
	H	6.42	6.47	6.55	6.96	6.96	7.14	7.55	7.04	6.45	4.08	4.08
N.A.T.P.	NH	9.49	9.49	9.66	10.30	11.20	12.50	13.90	15.40	16.30	18.90	21.50
	H	6.42	6.47	6.91	7.14	7.90	7.96	8.02	7.55	7.45	6.07	6.07
N.A.T.T.	NH	9.49	9.49	10.07	10.70	11.40	13.80	15.50	17.10	18.9	20.30	22.70
	H	6.42	6.47	7.45	7.81	8.25	9.92	9.97	9.92	9.04	7.73	7.73
N.A.T.H.	NH	9.49	9.49	9.63	10.20	10.90	12.50	13.70	15.30	14.70	19.30	20.90
	H	6.42	6.47	7.11	7.53	7.58	8.42	8.47	8.40	8.29	6.18	6.18
N.A.T.P.P.	NH	9.49	9.49	9.01	10.20	10.70	11.50	12.00	14.00	15.90	17.7	20.00
	H	6.42	6.47	7.14	7.40	7.40	7.50	7.92	7.77	7.01	4.93	4.93

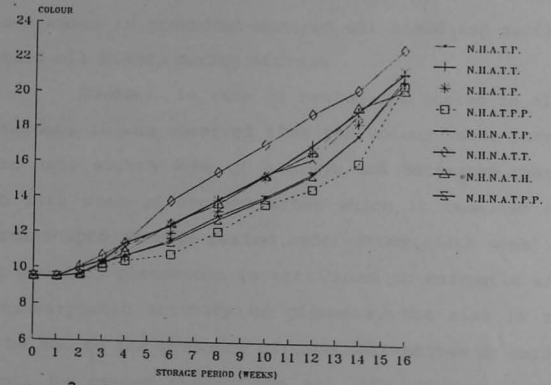


FIG 4. 3 VARIATIONS IN COLOUR OF NON HEATED SUNFLOWER OIL

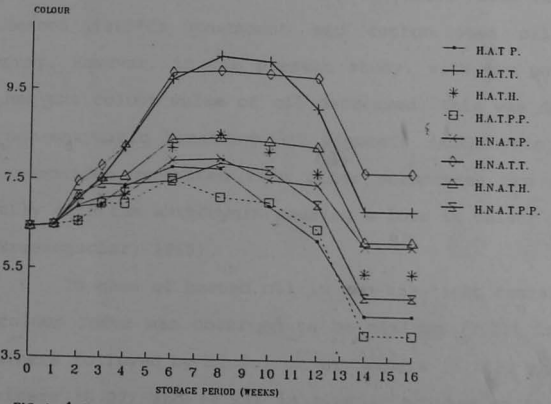


FIG 4. 4 VARIATIONS IN COLOUR OF HEATED SUNFLOWER OIL

However, Bagga et al. (1992) observed a fall in colour value in groundnut-mustard oil blend and sunflower-mustard oil blend, during storage.

However, in case of heated oil stored in all the containers it was observed that the colour value increased first upto eighth week of storage and decreased thereupon upto 14th week of storage after which it remained almost constant upto storage period under study (16th week). This rise and fall phenomenon is attributed to enzymatic as well as nonenzymatic activity of pigments. The rise in colour may be due to the presence of iron derivatives or oxidation of oil by oxygen present in oil. Same results were reported by Handoo et al. (1992) in pure groundnut and cotton seed oil. A significant rise in colour value in case of heated (180°C) groundnut and cotton seed oil was observed. However, in the present study, with the passage of time the colour value of oil decreased. This was due to the non-enzymatic breakdown of pigments (anthocynin). In this peroxides generated from other substrates can react directly with the anthocynin causing a loss in colour (Lamb and Sreeangachar, 1965).

In case of heated oil in non-air tight containers the colour index was observed to be maximum (7.73) in tin containers followed by hindolium containers (6.18), plastic containers (6.07) and (4.93) in plastic pouches at the end of storage period. However, at the end of 8th week the

colour number was 8.02, 9.97, 8.47, 7.92 for plastic, tin, hindolium and plastic pouches respectively.

A similar trend was observed for heated oil in air tight containers where the colour index was found to be maximum (6.88) in tin containers followed by hindolium containers (5.47), plastic containers (4.51) and plastic pouches (4.08) while at the end of 8th week the colour number was 7.81, 9.80, 8.24, 7.55, for plastic, tin, hindolium and plastic pouches respectively.

As mentioned above in non-heated non-air tight and non-heated air tight containers the colour value was found to be maximum (22.7) and (21.3) in tin containers. The fact can be attributed to the presence of iron derivatives which darkens the colour of oil because of increase in oxypolymer concentration (Carter, 1978). Morevoer, the difference in colour value of oil in non-heated non-air tight as well as air tight containers proves that the oxygen has a significant role in colour development of oil. The figure 4.3 shows clearly a significant rise in colour value of oil in non-heated non-air tight containers as compared to oil in non-heated air tight containers. This can be explained as the oxidation of oil in non-heated non-air tight containers (Bhatnagar and Singh, 1972).

The colour of oil in different containers at the end of storage period under study was (20.8, 21.3, 20.6,

Fig.4.5 A View of Colour of Non Heated Oil Samples at the 16th Week

1. NHATP
2. NHATT
3. NHATH
4. NHATPP
5. NHNATP
6. NHNATT
7. NHNATH
8. NHNATPP

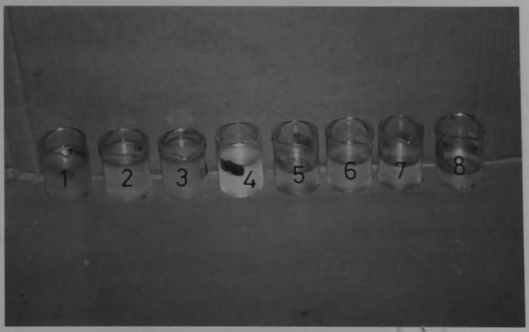


Fig.4.6 A view of Colour of Heated Oil Samples at the 16th Week

1. NHATP
2. NHATT
3. NHATH
4. NHATPP
5. NHNATP
6. NHNATT
7. NHNATH
8. NHNATPP

21.5, 22.7, 20.9, 21.0, 4.51, 6.88, 5.47, 4.08, 6.07, 7.73, 6.18 and 4.93) for NHATP, NHATT, NHATH, NHATPP, NHNATP, NHNATT, NHNATH, NHNATPP, HATP, HATT, HATH, HATPP, HNATP, HNATT, NHATH, and NHATPP containers respectively. This shows that heated air tight plastic pouches have lowest values amongst all the containers and thus these are the best containers out of all under study for sunflower oil storage as far as colour property is concerned.

The colours of various samples observed at the end of the storage period were as shown in figures 4.5 and 4.6.

4.1.3 Effect on odour

The variations in odour during the storage period for all the containers are presented in Table 4.3 and plotted in figures 4.7 and 4.8 respectively.

The odour values shown in the tables are the panel scores. The more is the panel score the better is the odour of oil and vice-versa.

From the data presented in tables and figures it is observed that the odour value decreased in all the containers throughout the storage period under study for non-heated as well as heated oils and for non-air tight and air tight containers. The panel score for non-heated and heated oils stored in non-air tight and air tight containers at the beginning of storage studies was 15.00.

TABLE 4.3: VARIATIONS IN ODOUR OF SUNFLOWER OIL WITH STORAGE PERIOD

Containers	Treatments	Storage Period (Weeks)									
		0	1	2	3	4	6	8	10	12	14	16
A.T.P.	NH	15.00	15.00	11.60	11.60	10.00	8.33	6.66	6.66	6.66	5.00	3.33
	H	15.00	15.00	15.00	15.00	13.30	13.30	13.30	13.30	11.60	10.00	10.00
A.T.T.	NH	15.00	15.00	8.33	8.33	6.66	6.66	6.66	5.00	5.00	3.33	1.66
	H	15.00	15.00	10.00	10.00	8.33	8.33	8.33	8.33	8.33	5.00	5.00
A.T.H.	NH	15.00	15.00	13.30	13.30	11.60	10.00	10.00	8.33	8.33	8.33	3.33
	H	15.00	15.00	13.30	13.30	13.30	13.30	13.30	13.30	11.60	11.60	11.60
A.T.P.P.	NH	15.00	15.00	15.00	15.00	15.00	13.30	13.30	11.60	10.00	10.00	5.00
	H	15.00	15.00	15.00	15.00	15.00	13.30	13.30	13.30	13.30	13.30	13.30
N.A.T.P.	NH	15.00	15.00	10.00	10.00	8.33	6.66	6.66	6.66	6.66	5.00	3.33
	H	15.00	15.00	13.30	11.60	11.60	11.60	8.33	8.33	6.66	6.66	6.66
N.A.T.T.	NH	15.00	15.00	8.33	8.33	6.66	6.66	6.66	6.66	6.66	5.00	1.66
	H	15.00	15.00	10.00	10.30	8.33	6.66	6.66	6.66	5.00	5.00	5.00
N.A.T.H.	NH	15.00	15.00	10.00	10.00	10.00	10.00	10.00	10.00	8.33	6.66	1.66
	H	15.00	15.00	13.30	11.60	11.60	11.60	11.60	11.60	6.66	6.66	6.66
N.A.T.P.P.	NH	15.00	15.00	13.30	13.30	13.30	13.30	13.30	13.30	11.60	10.00	3.33
	H	15.00	15.00	13.30	13.30	13.30	13.30	13.30	13.30	10.00	10.00	10.00

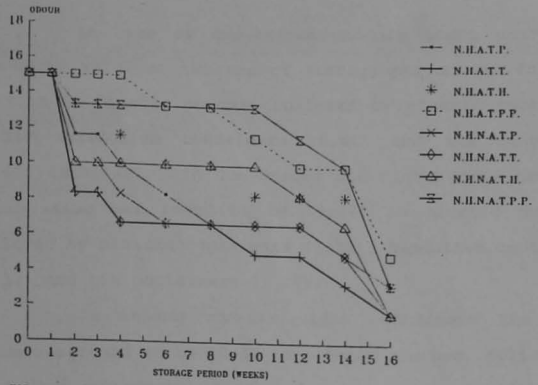


FIG 4.7 VARIATIONS IN ODOUR OF NON HEATED SUNFLOWER OIL

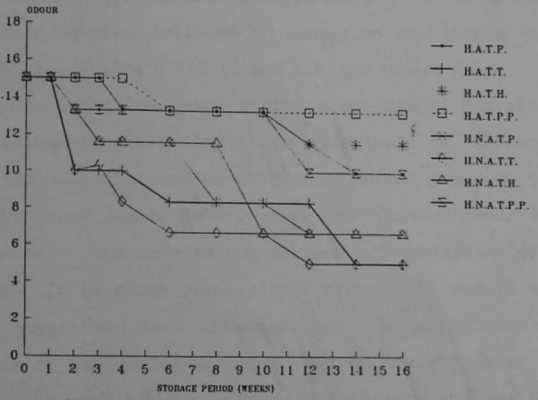


FIG 4.8 VARIATIONS IN ODOUR OF HEATED SUNFLOWER OIL

In case of non-heated non-air tight containers the odour value at the end of storage period was found to be 3.33 in plastic pouches followed by plastic containers (3.33), hindolium containers (1.66) and tin containers (1.66). Similarly, in non-heated air tight containers the odour value was found to be (5.00) in plastic pouches, followed by plastic containers (3.33), hindolium containers (3.33) and tin containers (1.66).

In heated non-air tight containers the odour value was found to be 10.00 in plastic pouches, followed by hindolium containers (6.66), plastic containers (6.66) and tin containers (5.00). Similarly, in heated air tight containers the odour value was found to be (13.3), in plastic pouches followed by hindolium containers (11.60), plastic containers (10.0) and tin containers (5.0).

The low panel score in non-heated non-air tight containers and air tight containers leads to the bad odour in the oil. This can be attributed to the presence of iron derivatives which deteriorates the flavour/odour of oil because of increase in oxy-polymers concentration (Carter, 1978). It is shown clearly in figures (4.7) and (4.8) that the oxygen and heat treatment has a strong effect on the odour of oil during storage i.e. why the values of odours remained more in case of heated air tight and heated non-air tight containers. This shows that heated air tight

plastic pouches have maximum panel scores for odour (showing a good odour of the oil) at the end of the storage period and thus, these are the best containers out of all the containers under study for sunflower oil storage as far as odour is concerned.

4.2 Biochemical Parameters

4.2.1 Effect on Free Fatty Acid content (F.F.A./Acid Value

The variations in free fatty acid (%) during the storage period under study for all the containers are presented in table 4.4 and plotted in figures 4.9 and 4.10 respectively.

The initial value of F.F.A. of non-heated oil was 0.822 and that of heated oil was 0.846 per cent. This non-significant increrase in F.F.A. due to heating is because of open air heating of the oil since the temperature of oil increases slowly, so in the initial stages of heating the enzyme lipase gets the optimum tempearture for the hydrolytic breakdown of the fat for some time.

From the data presented in table 4.4 and figures 4.9 and 4.10, it is clear that the F.F.A. increased in all the containers throughout the storage period under study.

In case of non heated oils the F.F.A. increased up to the range of 2.41 (%) and in heated oils upto the range of 2.02 (%). It is observed that in case of non-

TABLE 4.4: VARIATIONS IN F.F.A. (IN PERCENTAGE) OF SUNFLOWER OIL WITH STORAGE PERIOD

Containers	Treatments	Storage Period (Weeks)										
		0	1	2	3	4	6	8	10	12	14	16
A.T.P.	NH	0.822	0.846	0.892	1.26	1.26	1.48	1.55	1.69	1.90	2.11	2.22
	H	0.846	0.822	1.24	1.31	1.41	1.45	1.48	1.55	1.69	1.76	1.82
A.T.T.	NH	0.822	0.916	1.16	1.33	1.41	1.55	1.69	1.76	1.92	2.18	2.34
	H	0.846	0.916	1.28	1.33	1.43	1.52	1.55	1.64	1.76	1.90	1.96
A.T.H.	NH	0.822	0.822	1.12	1.19	1.34	1.40	1.55	1.62	1.76	1.94	2.15
	H	0.846	0.893	1.26	1.33	1.35	1.48	1.48	1.55	1.69	1.83	1.95
A.T.P.P.	NH	0.822	0.822	1.23	1.19	1.26	1.41	1.38	1.41	1.55	1.66	1.69
	H	0.846	0.892	1.09	1.21	1.21	1.26	1.26	1.28	1.41	1.52	1.60
N.A.T.P.	NH	0.822	0.869	1.33	1.41	1.48	1.66	1.69	1.78	1.90	2.18	2.32
	H	0.846	0.892	1.26	1.41	1.45	1.62	1.62	1.76	1.90	2.01	2.10
N.A.T.T.	NH	0.822	0.916	1.33	1.48	1.57	1.71	1.76	1.87	1.97	2.27	2.41
	H	0.846	0.869	1.23	1.43	1.48	1.64	1.69	1.80	1.97	2.06	2.12
N.A.T.H.	NH	0.822	0.869	1.28	1.41	1.50	1.59	1.49	1.76	1.90	2.21	2.55
	H	0.846	0.892	1.19	1.33	1.38	1.50	1.55	1.69	1.83	1.90	2.00
N.A.T.P.P.	NH	0.822	0.869	1.09	1.33	1.41	1.52	1.55	1.62	1.76	1.90	1.97
	H	0.846	0.822	1.19	1.26	1.48	1.45	1.48	1.50	1.62	1.78	1.97

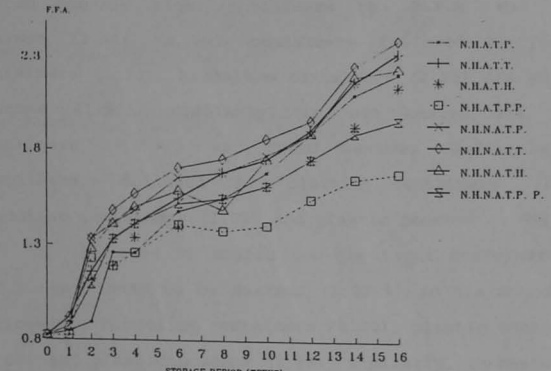


FIG 4.9 VARIATIONS IN F.F.A.(%) OF NONHEATED SUNFLOWER OIL

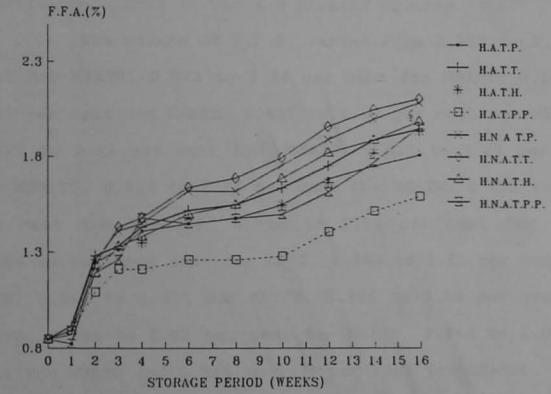


FIG 4.10 VARIATIONS IN F.F.A.(%) OF HEATED SUNFLOWER OIL

heated non-air tight containers the F.F.A. was found maximum (2.41) in tin containers followed by plastic containers (2.32), hindolium containers (2.25) and plastic pouches (1.97). Similarly, in non heated air tight containers (F.F.A.) was found maximum (2.34) in tin containers, followed by plastic containers (2.22), hindolium containers (2.05) and plastic pouches (1.69).

In case of heated non-air tight containers the F.F.A. was found to be maximum (2.02 %) in tin containers followed by hindolium containers (2.00), plastic containers (2.00) and plastic pouches (1.98). Similarly, in heated oil in air tight containers the F.F.A. was found maximum (1.96) in tin containers followed by hindolium containers (1.95), plastic containers (1.96) and plastic pouches (1.60).

The values of F.F.A. varied from 0.822 to 2.2 per cent for NHATP, 0.822 to 2.34 per cent for NHATT, 0.822 to 2.05 per cent for NHATH, 0.822 to 1.69 per cent for NHATPP, 0.822 to 2.32 per cent for NHNATP, 0.822 to 2.41 per cent for NHNATT, 0.822 to 2.25 per cent for NHATH, 0.822 to 1.97 per cent for NHNATPP, 0.846 to 1.82 per cent for HATP, 0.846 to 1.96 per cent for HATT, 0.846 to 1.95 per cent for HATH, 0.846 to 1.60% for HATPP, 0.846 to 2.00 per cent for HNATP, 0.846 to 2.02 per cent for HNATT, 0.846 to 2.00 per cent for HNATH and 0.846 to 1.98 per cent for HNATPP.

A close observation of figures 4.9 and 4.10 shows clearly that the rise in F.F.A. in heated non-air tight and

air tight containers is upto a range of 2.02 and 1.96 respectively as compared to the non heated non-air tight and non heated air tight containers where it was upto 2.41 to 2.31 respectively. It shows clearly that heat treatment and oxygen has a very strong effect on free fatty acid content of oil during the storage period under study and its increase is less in heated oils as compared to non heated oils.

Also, in case of non-air tight containers it is observed that the increase in F.F.A. is more almost in all the containers as compared to the air-tight containers. The non-heating and presence of O_2 in non-air tight containers are the reasons behind the increase in F.F.A. in all such conditions (as the fact can be attributed to the presence of iron derivatives and oxidation of oil in case of non-air tight oil samples). Similar results were reported by Sherwin and Luckadow (1972), Bhatnagar and Singh (1972) and Swern, Daniel (1979) in sunflower oil, rice bran oil and cotton seed oil respectively. However, the rise in F.F.A. in oil samples of non heated air tight containers may be due to the enzymatic breakdown of oil as well as nonenzymatic breakdown (Singh, 1979).

Since the variation in F.F.A. is lowest in plastic pouches in all the cases, hence it can be inferred that the plastic pouches are the best packaging material out of all the materials under study for sunflower oil

TABLE 4.5 : VARIATIONS IN ACID VALUE OF SUNFLOWER OIL WITH STORAGE PERIOD

Containers	Treatments	Storage Period (Weeks)										
		0	1	2	3	4	6	8	10	12	14	16
A.T.P.	NH	1.63	1.68	1.77	2.50	2.50	2.94	3.08	3.36	3.78	4.19	4.41
	H	1.68	1.68	2.46	2.60	2.80	2.88	2.94	3.08	3.36	3.50	3.62
A.T.T.	NH	1.63	1.82	2.30	2.64	2.80	3.08	3.36	3.50	3.82	4.33	4.65
	H	1.68	1.82	2.54	2.64	2.84	3.02	3.08	3.26	3.50	3.78	3.18
A.T.H.	NH	1.63	1.63	2.22	2.36	2.66	2.80	3.08	3.22	3.50	3.86	5.87
	H	1.68	1.77	2.50	2.64	2.68	2.94	2.94	3.08	3.36	3.64	3.88
A.T.P.P.	NH	1.63	1.63	2.44	2.36	2.50	2.80	2.74	2.80	3.08	3.30	3.36
	H	1.68	1.77	2.16	2.40	2.40	2.50	2.50	2.54	2.80	2.38	3.18
N.A.T.P.	NH	1.63	1.72	2.64	2.80	2.94	3.30	3.36	3.54	3.78	4.33	4.61
	H	1.68	1.77	2.50	2.80	2.88	3.22	3.22	3.50	3.78	3.99	3.98
N.A.T.T.	NH	1.63	1.82	2.64	2.94	3.12	3.40	3.50	3.72	3.92	4.51	4.79
	H	1.68	1.72	2.44	2.85	2.94	3.26	3.36	3.58	3.92	4.09	4.01
N.A.T.H.	NH	1.63	1.72	2.54	2.84	2.98	3.16	3.18	3.50	3.78	4.39	4.47
	H	1.68	1.77	2.36	2.64	2.74	2.98	3.08	3.36	3.64	3.78	3.98
N.A.T.P.P.	NH	1.63	1.72	2.16	2.64	2.80	3.02	3.08	3.22	3.50	3.78	3.92
	H	1.68	1.63	2.36	2.50	2.94	2.88	2.94	2.98	3.22	3.54	3.94

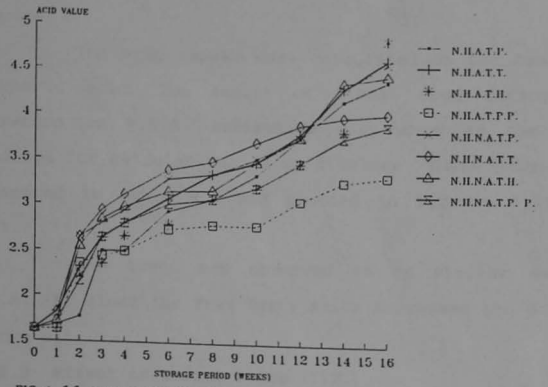


FIG 4. 11 VARIATIONS IN ACID VALUE OF NON HEATED SUNFLOWER OIL

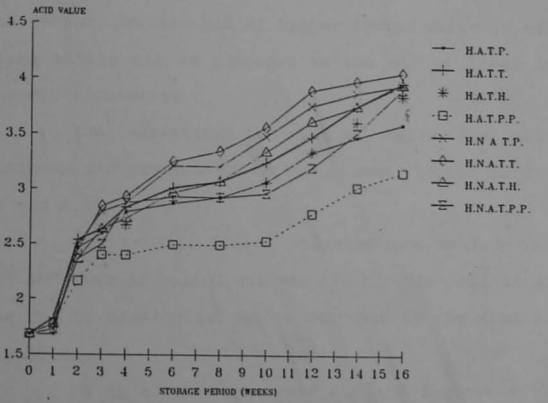


FIG 4. 12 VARIATIONS IN ACID VALUE OF HEATED SUNFLOWER OIL

storage.

The acid values were calculated on the basis of sulphuric acid. The amount of alkali used during the titration in F.F.A. estimation was taken as the base readings for calculations of acid values. These values are presented in table 4.5 and plotted in figures 4.11 and 4.12.

The trend was observed to be similar as for F.F.A. (%) since the Free Fatty Acids increased the acidity of the oil.

4.2.2 Effect on Iodine Value (I.V.)

Iodine value refers to the degree of unsaturation of fatty acids. More the iodine value more is the degree of unsaturation. So, the oil of higher iodine value is of good quality edible oil as compared to the oil of lower iodine value and vice-versa.

The variations in iodine value for all the containers are present in table 4.6 and plotted in figures 4.13 and 4.14.

The initial iodine value of non heated oil was 137.9 and that of heated oil was 136.0. This fall in iodine value due to heating is due to decrease in the unsaturated fatty acids.

It is clear from table 4.6 and figures 4.13 and 4.14 that iodine value decreases in all the containers throughout the storage period under study. It decreases

TABLE 4.6: VARIATIONS IN IODINE VALUE OF SUNFLOWER OIL WITH STORAGE PERIOD

Containers	Treatments	Storage Period (Weeks)										
		0	1	2	3	4	6	8	10	12	14	16
A.T.P.	NH	137.9	132.4	132.4	131.0	131.5	129.9	129.3	128.4	127.8	126.6	126.3
	H	136.9	135.4	127.8	131.6	130.5	129.7	129.3	128.6	127.6	127.2	127.0
A.T.T.	NH	137.9	137.6	132.9	132.0	131.6	129.7	129.1	128.0	126.8	125.7	125.5
	H	136.9	136.1	127.8	130.7	130.5	129.1	128.8	128.4	127.8	127.0	126.8
A.T.H.	NH	137.9	136.2	136.0	132.2	131.6	129.5	128.4	127.8	127.2	126.65	126.3
	H	136.9	136.7	130.3	129.9	129.5	129.7	129.3	128.4	127.8	127.0	124.0
A.T.P.P.	NH	137.9	135.4	133.3	131.4	131.6	129.0	129.3	128.4	127.6	126.8	126.6
	H	136.9	136.0	130.3	133.0	125.7	129.7	129.7	129.1	128.2	127.2	127.2
N.A.T.P.	NH	137.5	136.2	130.7	129.7	129.7	129.9	123.8	123.2	122.0	122.1	122.1
	H	136.9	137.3	134.8	132.2	131.2	129.1	129.1	128.0	127.2	126.3	125.7
N.A.T.T.	NH	137.9	136.3	124.9	124.4	124.2	123.6	123.2	122.6	121.7	121.5	121.7
	H	136.9	135.4	132.4	131.8	130.5	128.2	127.6	127.2	126.6	125.5	124.9
N.A.T.H	NH	137.9	136.2	126.1	126.1	124.9	123.8	123.0	122.5	121.7	121.5	121.5
	H	136.9	133.5	132.9	132.2	130.7	129.3	128.6	138.2	127.2	125.5	125.3
N.A.T.P.P.	NH	137.9	135.6	127.2	125.7	125.1	124.2	123.6	123.2	122.3	122.7	122.7
	NH	136.9	136.7	134.3	132.9	131.6	129.5	129.1	128.4	127.2	126.3	126.0

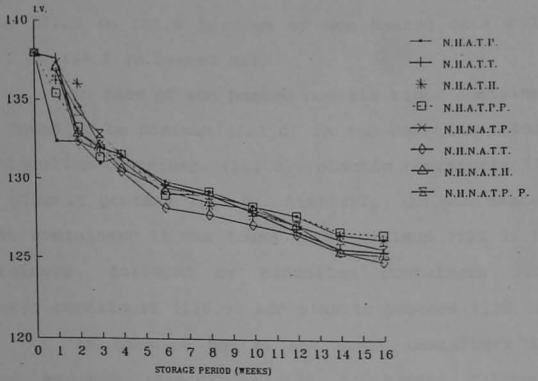


FIG 4. 13 VARIATIONS IN I.V. OF NON HEATED SUNFLOWER OIL

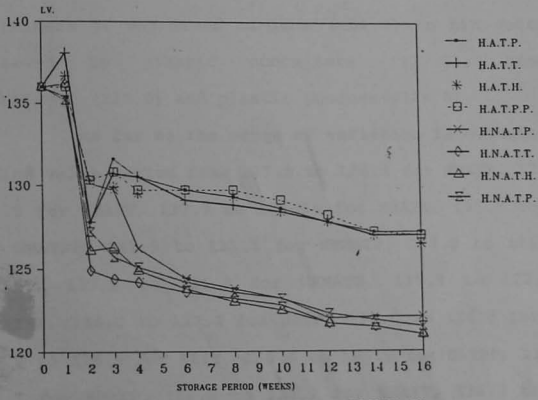


FIG 4..14 VARIATIONS IN I.V. OF HEATED SUNFLOWER OIL

from 137.9 to 121.0 in case of non heated oils and from 136.0 to 124.9 in heated oils.

In case of non heated non-air tight containers it was found to be minimum (121.0) in tin containers followed by hindolium containers (121.0), plastic containers (122.1) and plastic pouches (122.3). Similarly, in non heated air tight containers it was found to be minimum (125.5) in tin containers, followed by hindolium containers (126.3), plastic containers (126.3) and plastic pouches (126.6).

In case of heated air tight containers it was found minimum (124.9) in tin containers followed by hindolium containers (125.9), plastic containers (125.7) and plastic pouches (126.0). Similarly in heated air tight containers it was found minimum (126.0) in tin containers followed by plastic containers (127.2), hindolium containers (127.0) and plastic pouches (127.0).

As far as the range of variation is concerned the iodine value varied from 137.9 to 126.3 for NHATP, 137.9 to 125.5 for NHATT, 137.9 to 126.34 for NHATH, 137.9 to 126.6 for NHATPP, 137.9 to 121.1 for NHNATP, 137.9 to 121.0 for NHNATT, 137.9 to 121.0 for NHNATH, 137.9 to 122.3 for NHNATPP, 136.0 to 127.2 for HATP, 136.0 to 126.0 for HATT, 136.0 to 126.5 for HATH, 136.0 to 127.0 for HATPP, 136.0 to 125.7 for HNATP, 136.0 to 124.9 for HNATT, 136.0 to 125.3 for HNATH and 136.0 to 126.0 for NHATPP.

As mentioned above the iodine value was observed to be minimum in case of non heated non-air tight (121.0) and non heated air tight containers (125.5). It shows that degree of unsaturation leading to deterioration of oils is low and it is because of oxidation of oil that causes the decrease in unsaturated fatty acids responsible for the fall in iodine value. A direct fall in iodine value during storage previously was observed by Bagga et al. (1992) and Handoo et al. (1992) respectively. In case of heated oil either in non-air tight or air tight containers a decrease in iodine value was observed and it was found minimum in tin containers. The fact can be attributed to the presence of iron derivatives and nonenzymatic breakdown of oil. Similarly, a significant fall in iodine value was observed in case of heated oil (180°C) by Handoo et al. (1992).

Since the variation in iodine value is observed to be lowest in plastic pouches. Hence it can be inferred that this is a good packaging material for sunflower oil storage out of the materials under study. The same material was also observed to be good from F.F.A. value point of view.

4.2.3 Effect on Saponification Value (S.V.)

The variations in saponification value for all the containers during storage period under study are presented in table 4.7 and plotted in figures 4.15 and 4.16. The more is the saponification value the better is the oil and vice versa.

TABLE 4.7 VARIATIONS IN SAPONIFICATION VALUE OF SUNFLOWER OIL WITH STORAGE PERIOD

Containers	Treatments	Storage Period (Weeks)										
		0	1	2	3	4	6	8	10	12	14	16
A.T.P.	NH	189.3	186.3	176.6	170.6	163.6	163.6	154.2	149.2	144.8	140.2	140.2
	H	189.3	189.3	191.3	189.3	180.6	173.6	161.9	159.5	142.5	146.8	140.2
A.T.T.	NH	189.3	189.3	177.6	172.9	168.7	158.8	154.2	147.2	140.2	133.2	131.3
	H	189.3	186.3	177.6	172.6	168.3	151.8	144.8	142.5	135.5	132.2	132.2
A.T.H.	NH	189.3	189.3	177.6	175.3	170.6	161.2	151.8	147.2	142.5	135.5	140.2
	H	189.3	184.6	180.9	179.9	172.5	163.2	154.2	147.2	142.5	135.5	140.2
A.T.P.P.	NH	189.3	189.3	189.3	184.6	175.3	168.2	151.8	144.8	144.2	142.2	141.5
	H	189.3	188.6	189.3	184.3	182.3	175.3	158.8	147.2	142.6	142.6	142.0
N.A.T.P.	NH	189.3	189.3	172.9	172.9	163.6	149.5	142.5	137.6	133.2	131.3	127.6
	H	189.3	190.3	179.9	172.9	168.2	158.9	142.5	144.9	140.2	140.2	140.2
N.A.T.T.	NH	189.3	186.5	170.6	165.9	158.8	149.5	140.2	137.9	133.2	126.2	124.5
	H	189.3	187.6	172.9	168.3	158.8	149.5	140.2	137.9	133.2	126.2	126.0
N.A.T.H.	NH	189.3	184.3	175.3	170.6	161.2	151.8	147.2	144.8	133.5	132.2	130.4
	H	189.3	189.3	184.6	177.6	172.9	151.8	147.6	142.5	137.8	133.2	133.2
N.A.T.P.P.	NH	189.3	189.3	173.5	175.3	163.5	156.5	151.8	147.2	142.5	137.8	133.2
	H	189.3	189.3	184.6	182.3	177.3	156.5	151.8	144.8	142.5	140.2	140.2

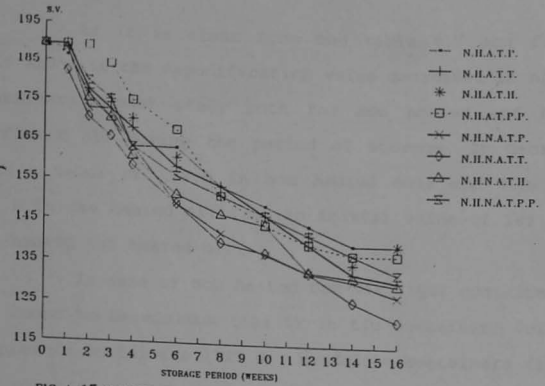


FIG 4.15 VARIATIONS IN S.V. OF NON HEATED SUNFLOWER OIL

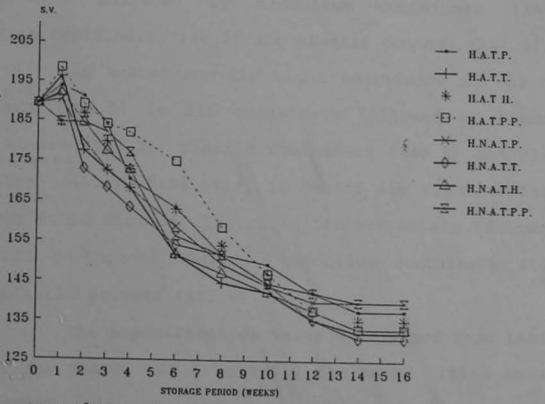


FIG 4.16 VARIATIONS IN S.V.OF HEATED SUNFLOWER OIL

As it is clear from the table 4.7 and figures 4.15 and 4.16 the saponification value decreased in all the containers under study both for non heated and heated sunflower oil during the period of storage. It decreased upto a value of 124.5 in non heated oils and upto 126.0 in the heated oil from an initial value of 189.3 for non-heated and heated oil.

In case of non heated non-air tight containers it was found to be minimum (124.5) in tin containers followed by plastic containers (127.6), hindolium containers (130.4) and plastic pouches (133.2). Similarly in non heated air tight containers it was found minimum (131.3) in tin containers followed by hindolium containers (140.2), plastic containers (140.2) and plastic pouches (141.5).

In heated non-air tight containers it was found minimum (126.0) in tin containers followed by hindolium containers (133.2), plastic containers (140.2) and plastic pouches (140.2). Similarly, in heated air tight containers it was found minimum (132.2) in tin containers followed by plastic containers (140.2), hindolium containers (140.2) and plastic pouches (142.0).

The saponification value decreased from 189.3 to 140.2 for NHATP, 189.3 to 140.2 for NHATP, 189.3 to 131.3 for NHATT, 189.3 to 140.2 for NHATH, 189.3 to 141.5 for NHATPP, 189.3 to 127.6 for NHNATP, 189.3 to 124.5 for

NHNATT, 189.3 to 130.4 for NHNATH, 189.3 to 133.2 for NHNATPP, 189.3 to 140.2 for HATP, 189.3 to 132.2 for HATT, 189.3 to 140.2 for HATH, 189.3 to 142.0 for HATPP, 189.3 to 140.2 for HNATP, 189.3 to 126.0 for HNATT, 189.3 to 133.2 for HNATH and 189.3 to 140.2 for HNATPP.

As mentioned above the fall in S.V. of non heated, non-air tight and air tight containers was found maximum. This is due to the deterioration of fatty acids through oxidation and formation of peroxides because of the enzymatic breakdown of oil. However, in case of heated oil in non-air tight and air tight containers, the saponification values were found much higher as compared to the non heated non-air tight and air tight containers. It establishes the fact that heat treatment and air tightness had a strong effect on saponification value during the storage of oil.

Since the variation in saponification value is lowest in plastic pouches, hence these are the best packaging material out of all under study for sunflower oil storage.

4.3 Comparison of Observed Physical and Biochemical Properties with Standard Values is given in table 4.8.

A close look of table 4.8 shows that the specific gravity remained almost unchaged throughout the storage period of study and also the colour value never crossed the standard value of 20 even at the end of 16th week of the

Table 4.8 Comparison of Observed Physical and Biochemical Properties with Standard Values

Containers	Specific gravity		Colour		Odour		F.F.A.**		Acid value		Iodine value		Sp.value	
	S.V.	Week*	S.V.	Week*	S.V.	Week*	S.V.	Week*	S.V.	Week*	S.V.	Week*	S.V.	Week*
NHNATP	0.901	Remained unchanged (0.901) even after 16 weeks	20.0	Does not cross the standard value even after 16 weeks	No specifications are given in B.I.S. and A.O.A.C.	X	1.5	5	3.0	5	100-140	Does not go below the minimum value of 100 even at the end of 16th week	188-194	2
NHNATT								4		4				1
NHNATH								5		5				1
NHNATPP								6		6				2
NHATP								8		8				1
NHATT								6		6				2
NHATH								8		8				2
NHATPP								12		12				3
HNATP								5		5				2
HNATT								5		5				1
HNATH								7		7				2
HNATPP								11		11				2
HATP								10		10				2
HATT								6		6				1
HATH								10		10				1
HATPP								14		15				3

* No. of weeks at which it crossed standard value (S.V.)

**Standard value of F.F.A. is according to srtandard acid value 3.

Sp. Sponification

storage in any of the containers under different treatments. The idoine value also remained within the standard range of 100 to 140 in all the containers and treatments under study even at the end of storage period. For odour there are no specific values mentioned in the standards for oil. Therefore no comparison can be made. Therefore, it can be concluded that specific gravity, colour and iodine values are not the critical properties for all the containers and treatments under study for sunflower oil upto 16th week of storage.

Further observation of table 4.8 shows that F.F.A./Acid Value is a critical property to be observed for sunflower oil storage. Out of the materials and containers under study it is observed that the F.F.A./Acid Value of sunflower oil crosses the standard value of 1.5 and 3.0 respectively after 4 weeks in NHNATT, after 5 weeks in NHNATH, NHNATP, HNATP, HNATT, after 6 weeks in NHATT, NHNATPP, HATT, after 7 weeks in HNATH, after 8 weeks in NHNATP, NHNATH, after 10 weeks in HATP, HATH, after 11th week in HNATPP, after 12th week in NHATPP, after 15th week in HATPP.

It is also observed from table 4.8 that the saponification value comes down the minimum standard value of 188 in first, second or third week of storage. If we take saponification value as the single criteria for

quality then the oil would have become unfit for consumption after 2nd or 3rd week of storage. However, this is not the case, because saponification value of a fat or oil is the measure of the mean molecular weight of the fatty acids present in fat. In case of sunflower oil also the free fatty acids liberated in the initial stages might have been of higher molecular weight thus lowering its saponification value and unaffecting the F.F.A./Acid Value. Therefore, in this study the only criteria left for quality is F.F.A./Acid Value as quality parameter. According to which oil can safely be stored upto a maximum of 14/15 weeks in the air tight plastic pouch with heated oil. In other containers both for non-heated and heated oil this period is lesser with minium value of 4 weeks in non-air tight tin (NATT) with non-heated oil.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of the present work were:

1. To study the storage behaviour of sunflower oil stored in different containers under aerated and non-aerated conditions.
2. To study the effect of heat treatment on storage of sunflower oil under aerated and nonaerated conditions.

An experiment to study the effect of heat treatment, air tight and non-air tight storage conditions in tin, plastic, hindolium containers and plastic pouches on the storability of sunflower oil was undertaken. The crude oil as well as heated oil (120°C, 90 minutes duration) was stored in tin, plastic, hindolium containers 2 kg each and plastic pouches 100 g each under air tight and non-air tight conditions for 3 months and 11 days from June to October, 1995. The different parameters studied to find out the changes caused in oil during storage were variations in specific gravity, colour number, odour value, free fatty acid content (%), iodine value and

saponification value.

The following conclusions were drawn:

1. The specific gravity of oil remained almost same in all the packaging materials during the storage period under study.

2. The colour number/index in general increased in case of non heated, non-air tight and air tight conditions. The rise in colour number/index was more under non-air tight storage conditions. The rise in colour value was least in air tight, plastic pouches, followed by hindolium, plastic and tin containers. There was no appreciable difference in air tight, hindolium and plastic containers. However, non-air tightness in tin containers increased the colour number/index due to its iron content. However, in case of heated air tight and non-air tight storage conditions, the colour number/index first increased upto 8th week and then decreased upto 14th week and thereafter remained constant for the last two weeks.

3. The odour value decreased in all the packaging materials. Heated air tight plastic pouches are found to be best packaging materials followed by heated non-air tight plastic pouches, non heated air tight plastic pouches and non heated non air

tight plastic pouches. Hindolium and plastic containers almost show the same performance under all the storage conditions. Tin containers were not found to be suitable for oil storage from odour point of view.

4. Free fatty acid content in general increased during the storage period. The increase was minimum in plastic pouches under all the conditions. Non-air tightness increased free fatty acid content. Heat treatment and air tightness was found effective in checking the increase in F.F.A.. Tin containers were not found suitable for oil storage from F.F.A. point of view. Plastic pouches were found to be best packaging material followed by hindolium and plastic containers under all the storage conditions.

5. Iodine value in general decreased during storage. The decrease was minimum in plastic pouches under all the conditions. Non-air tightness increased the fall in iodine value. Heat treatment and air tightness were found to be effective as these reduced the fall in iodine value. Tin containers were not found suitable for oil storage from iodine value point of view. Plastic pouches were found to be best packaging material followed by

hindolium and plastic containers, under all the storage conditions.

6. Saponification value in general decreased during storage. The decrease was minimum in the plastic pouches under all the conditions. Non-air tightness increased the fall in saponification value. Heat treatment and air tightness were found effective as it reduced the fall in saponification value. Tin containers are not found suitable for oil storage from saponification value point of view also. Plastic pouches were found to be best packaging material. No appreciable differences were observed in hindolium and plastic containers, under all the storage conditions.

7. The specific gravity, colour and idone value are not found to be the critical properties for all the containers and treatments under study for sunflower oil upto 16th weeks of storage as these remained within the standard range of values.

8. F.F.A./Acid Value is found to be a criticial property for sunflower oil storage. According to these the oil can safely be stored upto a maximum of 14/15 weeks in airtight plastic pouch with heated oil. In other containers both for nonheated and heated oil, this period is lesser

with minimum value of 4 weeks in non-air right tin (NATT) with non-heated oil.

9. If saponification value is taken as the single criteria for quality then the oil would have become unfit for consumption after second or third week of storage. However, this is not the case because saponification value of a fat or oil is the measure of the mean molecular weight of the fatty acids present in the fat. In case of sunflower oil also the free fatty acids liberated in the initial stages might have been of higher molecular weight thus lowering its saponification value and unaffecting the F.F.A./Acid Value. Therefore, in this study only critria left for quality is F.F.A./Acid Value as quality parameter.

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APPENDICES

APPENDIX -A

TABLE A-1: OBSERVED VALUES OF SPECIFIC GRAVITY IN DIFFERENT TYPES OF CONTAINERS UNDER DIFFERENT TREATMENTS DURING SUNFLOWER OIL STORAGE

Containers	Storage Period (Weeks)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N.H.A.T.P.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.H.A.T.T.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.H.A.T.H.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.H.A.T.P.P.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.H.N.A.T.P.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.H.N.A.T.T.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.H.N.A.T.H.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
N.H.N.A.T.P.P.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
H.A.T.P.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
H.A.T.T.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
H.A.T.H.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
H.A.T.P.P.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
H.N.A.T.P.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
H.N.A.T.T.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
H.N.A.T.H.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
H.N.A.T.P.P.	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901

TABLE A-2: OBSERVED VALUES OF COLOUR NUMEBR/INDEX IN DIFFERENT TYPES OF CONTAINERS UNDER DIFFERENT TREATMENTS DURING SUNFLOWER OIL STORAGE

Containers	Storage Period (Weeks)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N.H.A.T.P.	9.49	9.49	9.62	10.30	10.70	11.70	11.60	12.60	13.00	13.80	14.10	14.80	15.50	16.30	17.70	19.30	20.80
N.H.A.T.T.	9.49	9.49	10.00	10.40	11.40	11.80	12.40	13.30	13.90	14.50	15.30	16.40	17.10	17.90	19.10	20.60	21.30
N.H.A.T.H.	9.49	9.49	9.62	10.20	10.60	11.50	12.00	12.60	13.0	14.40	15.20	15.90	16.70	17.40	18.40	20.10	20.70
N.H.A.T.P.P.	9.49	9.49	9.59	10.04	10.40	10.40	10.80	11.40	12.10	12.90	13.70	14.10	14.60	15.40	16.70	18.40	20.60
N.H.N.A.T.P.	9.49	9.49	9.66	10.30	11.20	12.20	12.50	12.60	13.90	14.60	15.40	15.80	16.30	17.00	18.90	20.80	21.50
N.H.N.A.T.T.	9.49	9.49	10.07	10.70	11.40	12.80	13.80	14.20	15.50	16.60	17.10	16.30	18.90	19.60	20.30	21.10	22.70
N.H.N.A.T.H.	9.49	9.49	9.63	10.20	10.90	11.90	12.50	13.00	13.70	14.5	15.30	18.40	16.7	17.10	19.30	20.10	20.90
N.H.N.A.T.P.P.	9.49	9.49	9.61	10.20	10.70	10.70	11.50	12.10	12.8	13.60	14.00	15.20	15.40	16.30	17.70	20.20	21.00
H.A.T.P.	6.42	6.47	6.88	6.94	7.35	7.40	7.79	7.81	7.79	7.32	6.96	6.88	6.19	5.78	4.51	3.69	3.69
H.A.T.T.	6.42	6.47	7.04	7.53	8.22	8.64	9.76	9.76	9.80	9.70	9.20	9.15	9.14	8.01	6.88	6.88	6.88
H.A.T.H.	6.42	6.47	6.58	6.91	7.17	7.40	8.24	8.24	8.24	8.24	8.17	8.11	7.70	6.73	5.47	4.36	4.36
H.A.T.P.P.	6.42	6.47	6.55	6.96	6.96	6.96	7.14	7.14	7.14	7.11	7.04	7.01	6.45	5.19	4.08	2.56	2.56
H.N.A.T.P.	6.42	6.47	6.91	7.14	7.40	7.55	7.96	8.02	8.02	7.8	7.55	7.50	7.45	6.86	6.07	4.95	4.80
H.N.A.T.T.	6.42	6.47	7.45	7.81	8.25	8.66	9.92	9.95	9.97	10.00	9.92	9.90	9.84	8.84	7.73	6.47	6.00
H.N.A.T.H.	6.42	6.47	7.11	7.53	7.58	7.66	8.42	8.47	8.47	8.47	8.40	8.35	8.29	7.47	6.10	5.36	5.12
H.N.A.T.P.P.	6.42	6.47	7.14	7.40	7.40	7.50	7.50	7.92	7.92	7.81	7.77	7.66	7.07	6.60	4.93	4.51	4.10

TABLE A-3: OBSERVED VALUES OF ODOUR IN DIFFERENT TYPES OF CONTAINERS UNDER DIFFERENT TREATMENTS DURING SUNFLOWER OIL STORAGE

Containers	Storage Period (Weeks)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N.H.A.T.P.	15.00	15.00	11.60	11.60	10.00	8.33	8.33	6.66	6.66	6.66	6.66	6.66	6.66	6.66	5.00	5.00	3.33
N.H.A.T.T.	15.00	15.00	8.33	8.33	6.66	6.6	6.66	6.66	6.66	4.00	5.00	5.00	5.00	5.00	3.33	3.33	1.66
N.H.A.T.H.	15.00	15.00	13.30	13.30	11.60	11.60	10.00	10.00	10.00	8.33	8.33	8.33	8.33	8.33	8.33	8.33	3.33
N.H.A.T.P.P.	15.00	15.00	15.00	15.00	15.00	13.30	13.30	13.30	13.30	11.60	11.60	11.60	10.00	10.00	10.00	10.00	5.00
N.H.N.A.T.P.	15.00	15.00	10.00	10.00	8.33	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	5.00	3.33	3.33
N.H.N.A.T.T.	15.00	15.00	8.33	8.33	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	5.00	3.33	1.66
N.H.N.A.T.H.	15.00	15.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	8.33	8.33	6.66	6.66	5.00	6.66
N.H.N.A.T.P.P.	15.00	15.00	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	11.60	11.60	10.00	8.33	3.33
H.A.T.P.	15.00	15.00	15.00	15.00	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	11.60	10.00	10.00	10.00	10.00
H.A.T.T.	15.00	15.00	10.00	1000	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	8.33	5.00	5.00	5.00	5.00
H.A.T.H.	15.00	15.00	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	11.60	11.60	11.60	11.60	11.60
H.A.T.P.P.	15.00	15.00	15.00	15.00	15.00	15.00	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30
H.N.A.T.P.	15.00	15.00	13.30	11.60	11.60	11.60	11.60	10.00	8.33	8.33	8.33	8.33	6.66	6.66	6.66	6.66	6.66
H.N.A.T.T.	15.00	15.00	10.00	10.30	8.33	6.66	6.66	6.66	6.66	6.66	6.66	6.66	5.00	5.00	5.00	5.00	5.00
H.N.A.T.H.	15.00	15.00	13.30	11.60	11.60	11.60	11.60	11.60	11.60	11.60	11.60	11.60	6.66	6.66	6.66	6.66	6.66
H.N.A.T.P.P.	15.00	15.00	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	13.30	10.00	10.00	10.00	10.00	10.00

Table A3a. Proforma for calculations of odour values

Samples		Men			Odour value
		M_1	M_2	M_3	
I	0_1	5	5	5	5+5+5 = 15
II	0_2	5	5	5	5+5+5 = 15
III	0_3	5	5	5	5+5+5 = 15

$$O = \frac{O_1 + O_2 + O_3}{3} = \frac{15 + 15 + 15}{3} = 15$$

TABLE A.4. OBSERVED VALUES OF F.F.A. IN DIFFERENT TYPES OF CONTAINERS UNDER DIFFERENT TREATMENTS DURING SUNFLOWER OIL STORAGE

Containers	Storage Period (Weeks)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N.H.A.T.P.	0.822	0.846	0.892	1.26	1.26	1.41	1.48	1.48	1.55	1.62	1.69	1.83	1.90	1.97	2.11	2.18	2.22
N.H.A.T.T.	0.822	0.916	1.16	1.33	1.41	1.48	1.55	1.62	1.69	1.76	1.76	1.87	1.92	1.94	2.18	2.27	2.34
N.H.A.T.H.	0.822	0.822	1.12	1.19	1.34	1.41	1.48	1.48	1.55	1.62	1.62	1.65	1.76	1.78	1.94	2.20	2.15
N.H.A.T.P.P.	0.822	0.822	1.13	1.19	1.26	1.28	1.41	1.28	1.38	1.41	1.41	1.48	1.55	1.59	1.66	1.69	1.69
N.H.N.A.T.P.	0.822	0.869	1.33	1.41	1.48	1.59	1.66	1.62	1.69	1.76	1.78	1.83	1.90	1.99	2.18	2.27	2.32
N.H.N.A.T.T.	0.822	0.916	1.33	1.48	1.57	1.62	1.71	1.71	1.76	1.83	1.87	1.90	1.97	2.06	2.27	2.32	2.41
N.H.N.A.T.H.	0.822	0.869	1.28	1.41	1.50	1.55	1.59	1.69	1.69	1.73	1.76	1.83	1.90	1.94	2.11	2.18	2.25
N.H.N.A.T.P.P.	0.822	0.869	1.09	1.33	1.41	1.45	1.52	1.52	1.55	1.59	1.62	1.69	1.76	1.83	1.90	1.94	1.97
H.A.T.P.	0.846	0.892	1.26	1.31	1.41	1.43	1.45	1.48	1.48	1.48	1.55	1.62	1.69	1.73	1.76	1.78	1.82
H.A.T.T.	0.846	0.916	1.28	1.33	1.43	1.45	1.52	1.55	1.55	1.55	1.64	1.69	1.76	1.83	1.90	1.94	1.96
H.A.T.H.	0.846	0.893	1.26	1.33	1.35	1.43	1.48	1.48	1.48	1.48	1.55	1.62	1.69	1.78	1.83	1.85	1.95
H.A.T.P.P.	0.846	0.892	1.09	1.21	1.21	1.21	1.28	1.26	1.26	1.26	1.28	1.33	1.41	1.48	1.52	1.55	1.60
H.N.A.T.P.	0.846	0.892	1.26	1.41	1.45	1.52	1.62	1.62	1.62	1.69	1.76	1.90	1.90	1.97	2.01	2.01	2.10
H.N.A.T.T.	0.846	0.869	1.23	1.43	1.48	1.52	1.64	1.69	1.69	1.78	1.80	1.92	1.97	2.01	2.06	2.08	2.12
H.N.A.T.H.	0.846	0.892	1.19	1.33	1.28	1.43	1.50	1.55	1.55	1.62	1.69	1.76	1.83	1.87	1.90	1.97	2.00
H.N.A.T.P.P.	0.846	0.976	1.19	1.26	1.28	1.38	1.45	1.48	1.48	1.48	1.50	1.55	1.62	1.69	1.78	1.83	1.97

TABLE A-5: OBSERVED VALUES OF ACID VALUE IN DIFFERENT TYPES OF CONTAINERS UNDER DIFFERENT TREATMENTS DURING SUNFLOWER OIL STORAGE

Containers	Storage Period (Weeks)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N.H.A.T.P.	1.63	1.68	1.77	2.50	2.50	2.80	2.94	2.94	3.08	3.22	3.36	3.64	3.78	3.92	4.19	4.33	4.41
N.H.A.T.T.	1.63	1.82	2.30	2.64	2.80	2.94	3.08	3.22	3.36	3.50	3.50	3.72	3.82	3.86	4.33	4.51	4.65
N.H.A.T.H.	1.63	1.63	2.22	2.36	2.66	2.78	2.80	2.94	3.08	3.22	3.22	3.28	3.50	3.54	3.86	4.37	5.87
N.H.A.T.P.P.	1.63	1.63	2.44	2.36	2.50	2.54	2.80	2.54	2.74	2.80	2.80	2.94	3.08	3.16	3.30	3.36	3.36
N.H.N.A.T.P.	1.63	1.72	2.64	2.80	2.94	3.16	3.30	3.22	3.36	3.50	3.54	3.64	3.78	3.96	4.33	4.51	4.61
N.H.N.A.T.T.	1.63	1.82	2.64	2.94	3.12	3.22	3.40	3.40	3.50	3.64	3.72	3.78	3.92	4.09	4.51	4.61	4.79
N.H.N.A.T.H.	1.63	1.72	2.54	2.84	2.98	3.08	3.16	3.36	2.78	3.44	3.50	3.64	3.78	3.86	4.39	4.33	4.47
N.H.N.A.T.P.P.	1.63	1.72	2.16	2.64	2.80	2.88	3.02	3.02	3.08	3.16	3.22	3.36	3.50	3.64	3.78	3.86	3.92
H.A.T.P.	1.68	1.68	2.46	2.60	2.80	2.84	2.88	2.94	2.94	2.94	3.08	3.22	3.36	3.44	3.50	3.54	3.62
H.A.T.T.	1.68	1.82	2.54	2.64	2.84	2.88	3.02	3.08	3.08	3.08	3.26	3.66	3.50	3.64	3.78	3.86	3.18
H.A.T.H.	1.68	1.77	2.50	2.64	2.68	2.84	2.94	2.94	2.94	2.94	3.08	3.22	3.36	3.54	3.64	3.68	3.88
H.A.T.P.P.	1.68	1.77	2.16	2.40	2.40	2.40	2.50	2.50	2.50	2.50	2.54	2.64	2.80	2.54	2.38	3.08	3.18
H.N.A.T.P.	1.68	1.77	2.50	2.80	2.88	3.02	3.22	3.22	3.22	3.36	3.50	2.31	3.78	3.92	3.99	3.99	3.98
H.N.A.T.T.	1.68	1.72	2.44	2.85	2.94	3.02	3.26	3.36	3.36	3.54	3.58	3.82	3.92	3.99	4.09	4.13	4.01
H.N.A.T.H.	1.68	1.77	2.36	2.64	2.74	2.84	2.98	3.08	3.08	3.22	3.36	3.50	3.64	3.72	3.78	3.92	3.98
H.N.A.T.P.P.	1.68	1.63	2.36	2.50	2.94	2.74	2.88	2.94	2.94	2.94	2.98	3.08	3.22	3.36	3.54	3.64	3.94

TABLE A-6: OBSERVED VALUES OF IODINE VALUE IN DIFFERENT TYPES OF CONTAINERS UNDER DIFFERENT TREATMENTS DURING SUNFLOWER OIL STORAGE

Containers	Storage Period (Weeks)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N.H.A.T.P.	137.9	137.9	132.4	131.0	131.5	130.8	129.9	129.7	129.3	128.8	128.4	128.0	127.8	127.4	126.6	126.3	126.3
N.H.A.T.T.	137.9	137.6	132.9	132.0	131.6	131.03	129.7	129.5	129.1	129.1	128.0	127.2	126.8	126.1	125.7	125.3	125.5
N.H.A.T.H.	137.9	136.0	126.1	132.2	131.6	132.8	129.5	129.1	128.4	128.0	127.8	127.6	127.2	127.2	128.6	128.1	126.3
N.H.A.T.P.P.	137.9	135.4	133.3	131.4	131.6	130.8	129.0	129.9	129.3	128.8	128.0	128.2	127.8	127.6	126.8	126.8	126.6
N.A.T.P.	137.9	137.3	134.8	132.2	131.2	129.9	129.1	129.3	129.1	128.4	128.4	127.2	127.6	126.6	126.3	125.7	125.7
N.A.T.T.	137.9	137.3	132.4	137.8	130.5	129.9	128.2	128.0	127.8	127.6	128.2	127.0	126.6	126.1	125.1	125.3	124.9
N.A.T.H.	137.9	135.4	132.9	132.2	130.7	129.9	129.3	129.1	129.1	128.4	128.4	127.8	127.2	126.8	125.5	1125.7	125.3
N.A.T.P.P.	137.9	136.7	134.3	132.9	131.6	131.2	129.5	129.3	129.3	128.8	126.6	127.8	127.9	126.6	126.3	125.9	126.0
H.A.T.P.	136.0	135.4	127.8	131.6	130.5	130.1	129.7	129.7	128.8	129.1	128.4	128.2	127.8	127.6	127.2	127.0	127.0
H.A.T.T.	136.0	135.4	127.8	130.7	130.5	129.9	129.1	129.1	129.3	128.6	128.4	128.0	127.8	127.4	127.0	126.8	126.8
H.A.T.H.	136.0	136.7	130.3	129.9	129.5	130.3	129.7	129.5	129.3	129.1	129.1	128.4	123.8	127.4	127.0	127.0	127.0
H.A.T.P.P.	136.0	136.0	130.3	146.8	129.7	130.5	129.7	129.7	129.7	129.3	123.7	126.8	128.2	127.8	127.2	127.2	127.2
H.N.A.T.P.	136.0	136.2	130.1	129.7	129.7	125.7	124.4	124.0	123.8	123.6	122.8	122.6	117.6	122.1	122.1	122.1	122.1
H.N.A.T.T.	136.0	136.2	124.9	124.4	124.2	124.2	123.6	123.4	123.2	123.0	122.5	122.5	121.7	121.7	121.5	121.7	121.7
H.N.A.T.H.	136.0	136.2	126.1	125.3	124.9	124.4	123.8	123.8	123.6	123.0	122.8	123.2	123.2	121.7	121.5	121.5	121.5
H.N.A.T.P.P.	136.0	1356	127.2	125.7	125.1	124.9	124.2	124.0	125.6	123.4	123.4	123.4	122.3	122.1	121.9	122.7	122.7

TABLE A-7: OBSERVED VALUES OF SAPONIFICATION VALUE IN DIFFERENT TYPES OF CONTAINERS UNDER DIFFERENT TREATMENTS DURING SUNFLOWER OIL STORAGE

Containers	Storage Period (Weeks)																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N.H.A.T.P.	189.3	186.3	176.6	170.6	163.2	163.6	163.6	156.5	154.2	151.8	149.5	147.2	144.6	142.5	140.2	140.2	140.2
N.H.A.T.T.	189.3	189.3	177.6	172.9	168.3	163.5	158.8	156.5	154.2	149.5	147.2	144.8	140.2	137.8	133.2	130.8	131.3
N.H.A.T.H.	189.3	189.3	177.6	175.6	175.3	166.3	161.2	154.2	151.8	149.5	147.2	144.8	142.5	137.8	135.5	133.2	140.2
N.H.A.T.P.P.	189.3	189.3	189.3	184.6	175.3	175.3	108.2	154.2	151.8	151.8	144.8	142.5	140.2	137.8	137.8	137.8	141.5
N.H.N.A.T.P.	189.3	189.3	172.9	172.9	163.6	158.9	149.5	144.8	142.5	140.2	137.8	135.5	133.2	133.2	131.3	129.0	127.6
N.H.N.A.T.T.	189.3	186.5	170.6	165.9	158.8	154.2	149.5	142.5	140.2	137.9	137.9	155.5	133.2	133.2	126.2	123.8	121.5
N.H.N.A.T.H.	184.3	184.3	175.3	170.6	161.2	151.9	151.8	149.5	147.2	144.8	144.8	140.2	135.5	133.2	132.2	137.3	130.4
N.H.N.A.T.P.P.	184.3	184.3	179.9	175.3	163.5	158.8	156.5	154.2	151.8	147.2	147.2	144.8	142.0	135.8	137.8	135.6	133.2
H.A.T.P.	189.3	189.3	184.2	184.2	170.6	165.9	163.6	161.2	151.9	151.6	149.5	147.2	142.5	140.2	137.8	137.8	140.2
H.A.T.T.	189.3	186.3	182.3	172.6	168.3	165.9	151.8	147.2	144.8	144.8	142.5	140.2	135.5	133.2	132.2	131.3	131.3
H.A.T.H.	189.3	186.6	186.6	179.9	172.9	168.3	163.2	161.2	154.2	149.5	147.2	144.8	142.5	140.2	135.5	132.2	132.2
H.A.T.P.P.	189.3	188.6	189.3	184.3	192.3	179.9	175.3	168.3	158.8	149.5	147.2	142.5	137.8	135.5	133.2	132.2	132.2
H.N.A.T.P.	189.3	189.6	179.9	172.9	168.2	165.9	158.9	154.2	149.5	147.2	144.9	144.9	140.2	140.2	140.2	137.8	140.2
H.N.A.T.T.	189.3	187.6	172.9	168.3	158.8	158.8	149.5	140.2	137.9	137.9	133.2	133.2	133.2	133.2	120682	126.2	126.0
H.N.A.T.H.	189.3	189.3	184.6	177.6	172.9	156.3	151.8	149.5	147.2	144.8	142.5	142.5	137.8	133.2	133.2	133.2	133.2
H.N.A.T.P.P.	189.3	189.3	184.6	182.3	177.3	165.9	150.5	154.2	151.8	147.2	144.8	142.5	142.5	140.2	140.2	140.2	140.2

APPENDIX-B

Table B-1: Ambient conditions (Temp., R.H.) during the storage period

Week	Temperature (°C)		Relative Humidity (%)	
	Maximum	Minimum	Maximum	Minimum
0	38.3	26.4	71	39
2	38.6	27.0	64	59
2	35.4	27.5	77	50
3	35.6	27.5	91	60
4	35.2	27.0	86	56
5	34.4	27.0	79	62
6	29.2	24.4	97	82
7	31.4	26.0	92	78
8	29.6	25.0	92	83
9	28.4	19.0	94	82
10	33.2	22.4	87	68
11	34.4	24.4	93	67
12	36.0	21.6	77	57
13	35.5	21.0	83	47
14	34.0	20.5	84	36
15	34.4	22.0	86	39
16	28.2	19.5	88	50