UNIVERSITI PUTRA MALAYSIA

# EFFECT OF FEED ADDITIVES ON STORAGE QUALITY OF PALM KERNEL CAKE

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by

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A paper submitted to the
Faculty of Veterinary Medicine and Animal Science
Universiti Pertanian Malaysia
in partial fulfilment of the requirement for the
Degree of Doctor of Veterinary Medicine

UNIVERSITI PERTANIAN MALAYSIA

JANUARY 1985

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DAN SEMUA KELUARGA

"KASIH SAYANGMU ASAS KEJAYAANKU"

- HAIR

## ACKNOWLEDGEMENT

The author wishes to express his profound appreciation and gratitude to his supervisors, Dr. Pravee Vijchulata and Dr. Mohamed Mahyuddin Dahan, for their valuable suggestions, constructive critism and close guidance throughout the course of the project.

Special thanks and grateful to Dr. M.A. Augustine (Faculty of Food Science and Technology), Dr. S. Sivarajasingam (Malaysia Agricultural Research and Development Institute), Dr. Kassim (Faculty of Veterinary Medicine and Animal Science) and Puan Sariam (His Aunty) for their patience, guidance and encouragement.

Lastly, he wishes to thank his friends and the staffs of Animal Science Department (Faculty of Veterinary Medicine and Animal Science) and Food Biochemistry (Faculty of Food Science and Technology) for their helped in his project.

# ABSTRACT

An experiment was conducted to evaluate the effect of various levels of Santoquin (100, 175 and 250 ppm), Aflaban (200 ppm) combination of Santoquin ( 175 ppm) and Aflaban (200 ppm), and dehydration and heat treatment on the quality of Palm Kernel Cake kept in plastic bag and gunny sack at room temperature for 0, 7 14 and 28 days incubation.

The quality of untreated Palm Kernel Cake deteriorated significantly during storage. Rancidity was observed within 7 days of incubation. Palm Kernal Cake treated with Aflaban, combination of Santoquin and Aflaban, and dehydration and heat treatment significantly inhibited hydrolytic rancidity to within the range of current commercial specification for Palm.Kernal. This pattern of effect is the same whether the treated Palm Kernal Cake was kept in plastic bag or gunny sack.

Addition of Santoquin at 175 and 250 ppm, combination of Santoquin and Aflaban, and dehydration and heat treatment significantly inhibited oxidative rancidity to within the standard specification of Crude Palm Oil during storage. However, plastic bag was more effective in maintaining the quality of Palm Kernal Cake during storage when compared to gunny sack.

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# 1. INTRODUCTION

The fruit of the palm tree (Elaeis guinnesis) yields two kinds of oil. Palm oil is obtained from the fleshy covering and palm kernel oil from the kernel of the nut. The residue left after solvent extraction of the kernel oil is called palm kernel meal. Solvent extracted meals contain less than 2 percent residual oil, while screw pressed cakes contain between 6 to 9 percent (Bo Gohl, 1975; PORLA, 1983). The processing chart of palm oil production is illustrated in Appendix 1 (PORLA, 1982).

Malaysia is the largest producer of palm oil in the world, accounting for some 60.3 percent (3.5 million tonnes) of total world output (PORLA, 1983). In 1983, West Malaysia alone produced about 200,000 and 300,000 tonnes of solvent extracted and expeller press palm kernel cake respectively (Ganabathi, 1983). More than 90 percent of this output is exported overseas especially to the EEC countries to be used as feedstuff for livestocks. The remaining was used by local feedmillers and by commercial poultry and pig farmers (Ganabathi, 1983).

Solvent extracted palm kernel cake is mainly used in concentrate for dairy cattle in Europe. According to Morrison (1956) and Bo Gohl (1975) cattle consuming PKC tends to give milk with firm butter texture. Feeding PKC at 2 to 3 kg per day to adult cattle provide satisfactory results. Good results also, have been observed in pigs receiving up to 20 to 30 percent PKC in the ration. It tends to produce firm pork of good quality. Temperton and Dudley (1939) found that PKC was a satisfactory substitute for wheat middlings in poultry diet. Poultry consuming 5 to 20 percent of PKC in the ration did not show any adverse effect (Bo Gohl, 1975; Yeong, 1982). The chemical composition of PKC is shown in Appendix 2.

An important feature common to PKC is the high percentages of unsaturated fatty acids in the triglyceride molecules (Rossell, 1975) as illustrated in Appendix 3. The principal cause of deterioration and possible economic loss of PKC (especially PKC expeller) is through rancidity resulting from hydrolysis and oxidation which takes place at the double bond (unsaturation) sites in the triglyceride molecules. In general, the higher the degree of unsaturation, the more susceptible is to deterioration (McDonald, 1973; Sherwin, 1976).

Rancid PKC are unpalatable to animal and may even be toxic. This is usually manifested in the form of diarrhea liver problems or encephalitis (Bo Gohl, 1975).

The objectives of this study are to evaluate the effects of:

i. Santoquin (Ethoxyguin or 1,2, dihydro-6-ethoxy-2,2, 4-trimethylquinoline),

ii. Aflaban (Sorbic acid),

iii. The combination of Santoquin and Aflaban,

iv. Packaging materials, and

v. Dehydration and heat treatment

on the storage quality of PKC.

## 2. LITERATURE REVIEW

### 2.1 Lipid Hydrolysis.

Fat may be hydrolysed naturally by the activity of endogenous cell lipases present in the fresh fruit bunches. This enzymic activity becomes important only when there was a delay in the processing of fruit, premature cutting of the fresh fruit bunches and when over ripe fruits were excessively bruised (Bek-Nielsen, 1976). The enzyme however, are destroyed at temperature of 60°C.(Wilbaux, 1936; Bek-Nielson, 1976). Lipolysis may be the results of microbial lipases. These lipases are mostly derived from bacteria and molds which are mostly responsible for spoilage or biodeterioration of palm kernel cake (Turner, 1969; 1971; McDonald, 1973) Hydrolysis also occured in palm oil as long as water is present. This is known as chemical lipolysis (Dessasis, 1957).

Under normal condition the products of lipolysis are usually mixtures of mono-and diglycerids with fatty acids. Most of these are adourless and tasteless, but some of the short chain fatty acids, particularly butyric and caproic acids have extremely powerful tastes and smells. Where such a breakdown takes place in an edible fat it may frequently be rendered completely unacceptable to the consumer.

## 2.2 Lipid Oxidation

Lipid can become rancid as a consequence of autoxidation during storage. Oxidation of unsaturated fatty acid has been well reported (Lundberg, 1962) and unless mediated by other oxidants or enzymic system, proceeds through a free radical chain mechanism involving initiation, propagation and termination steps (Gray, 1978; Logani and Daries, 1979). Hydroperoxides are the major initial reaction products of fatty acids with oxygen. Subsequent reactions control both the rate of reaction and the nature of the products formed (Gray, 1978) (Appendix 4). These compounds may be responsible for the development of off-flavors or further reactions with other food constituents such as protein (Roubal and Tappel, 1966) (Appendix 5).

It was recognised that lipid oxidation in biological membranes is a very destructive process. Lipid oxidation has been implicated in liver cell injury caused by chemical (Litov et al., 1978) such as $CCl_4$, $BrCCl_3$, 1,1,2,2-tetra-chloroethane, ethylene bromide and ethanol. Lipid peroxidation has been proposed as a possible mechanism in the clinically important phenomenon of ozone toxicity (Goldstein et al., 1969; 1970) in which lung damage induced by ozone and nitrogen dioxide results (Mensel, 1971). Chio and Tappel (1969) reported that the reactions between peroxidized lipids and proteins have been shown to cause loss of enzyme activities, polymerization (Roubal and Tappel, 1966; 1971), polypeptide chain scission (Zirlin and Karel, 1969), accelerated the formation of brown pigments (Roubal, 1971; Braddock and Dugan, 1973) and the destruction of labile amino acid residues such as histidine, lysine, cysteine and methionine (Roubal and Tappel, 1966).

Lea (1962) reported that the composition of fat (nature and proportions of the unsaturated fatty acid present) is the most important characteristic feature affecting lipid oxidation. Other factors are as listed in Appendix 6.

## 2.3 Effect of Antioxidant on Oxidation

Backstrom (1927) proposed that entioxidants act by interupting reaction chain in the autoxidative mechanism. A simple mechanism which the antioxidants act as hydrogen donors or free radical acceptors was proposed by Bolland and Have (1947). From the kinetics of the reaction it appeared that the free radical acceptors react primarily with ROO.and not the R., as follows:

$ROO. + X H_2 \qquad ROOH + XH.$

$XH. + XH \text{ ------ } X + XH_2.$

where, X refers to a free radicle or an inhibitor or an antioxidant.

This finding was confirmed by Cooper and Melville (1951). Hommond et al., (1955) proposed a different mechanism involving complex formation, as follows:

$ROO. + XH_2 \text{ ------ } (ROOXH_2)$

$(ROOXH_2). + ROO. \text{ ------- stable products}$

Bichel and Kooyman (1956) suggested consecutive reactions as follows:

$XH_2 + ROO. \text{ ------- } XH. + ROOH$

$XH. + ROO. \text{ ------- stable product.}$

These appears to be a kinetic arguments against both of these latter mechanism, but it is suggested by Harle and Thomas (1957) that, where the kinetic mechanism fail to satisfy either mechanism, both may be operative.

Presently, antioxidants cleared under the Food, Drug,and Cosmetic Act, for addition to food fats and oils are butylated hydroxyanisole (BHA), butylated hydroxytoulene (BHT), propyl gallate (PG), dilauryl thiopropionate, gum guaic, lecithin, 2,4,5-trihydroxy butyrophenone, ethoxyquin and glycine. Of these, BHA, BHT and PG are the most widely used (Sherwin, 1978).

## 2.4 Effect of Santoquin on Oxidation

Santoquin or ethoxyquin (2,2,4-trimethyl-1,2-dihydro-6-ethoxyquinoline) was first used in rubber formulation and later adapted to be used in feeds, particularly on dehydrated alfalfa as a protective agent for carotenoids (Thompson, 1959; van der Veen and Olcott, 1964; Kowles et al., 1968), in fish meal (Wessels, 1971) and in food (Parke et al., 1973). In addition to its antioxidant activity, Ethoxyquin has been reported to have anticarciogenic effects in mice and rats (Wattenberg, 1972; Cumming and Walton, 1973; Ulland et al., (1973), to protect against dietory liver necrosis (Schwarz, 1958), heptotoxicity (Cawthrone et al., 1973), congenital abnormalities in rat (King, 1964) and exudative diathesis in chick (Combs and Scott, 1974) and to increase longevity in mice (Comfort et al., 1971). Similar effects have been attributed to other anti-oxidants as well (King, 1964; Black, 1974; Georgieff, 1971; Ulland et al., 1973).

In the United States, ethoxyquin is permitted at levels up to 150 ppm in animal feeds and dehydrated forage crops, and up to 100 ppm in paprika and chilli powder. Tolerences are also specified for ethoxyquin residues in milk, egg and animal tissue (Perfectti et al., 1981).

Ethoxyquin acts as an inhibiting factor to the free radical mechanism of glyceride autoxidation. Their ability to do this is based on their phenolic structure or the phenolic configuration within their molecular structure. The phenolic configuration functions as a free radical acceptor, thus terminating the oxidation at the initiation step. The antioxidant free radical which formed is stable and most importantly, will not propogate further oxidation of the glyceride. The maximum effect of Santoquin can be acheived only if they are intimately mixed or dissolved in the oil and are added soon enough to inhibit or interrupt the free radical mechanisms of vegetable oil autoxidation (Sherwin, 1976) (Figure 1).

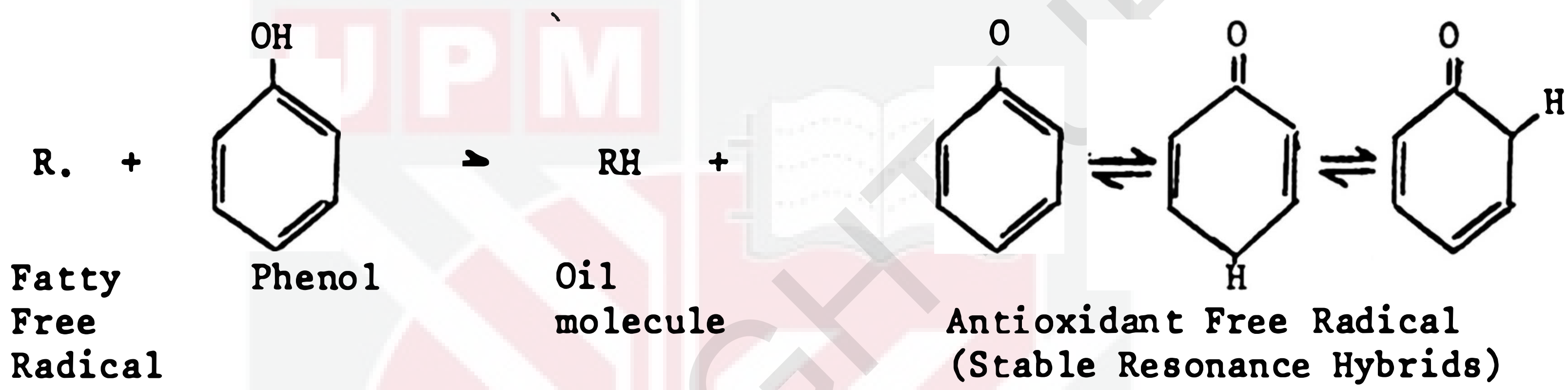


Figure 1: Phenolic antioxidant mechanism.

## 2.5 Effect of Fungistatic Compounds on Fungal Growth

Several antifungal compounds were compared for fungistatic activity by Chen and Day (1974). Among the compound tested, gential violet was found to have the highest overall activity. In a later study by Stewart et al., (1977), crystal violet and propionic acid were more effective than copper sulfate, calcium pripionate or sodium propionate in retarding mould growth. Lord and Lacey (1978) found that addition of 8-hydroxy quinoline to propionic acid in hay diminished the amount of the propionic required to prevent mould growth, possibly to inhibiting organisms tolerant of fatty acids and able to metablise them. Use of additives to pripionic or other acids may also limit the spread of such fungi from poorly treated hay into adjacent hay that would otherwise have been adequately treated to prevent spore germination.

Aflaban (Sorbic acid) is a widely used preservative in human foods (Dilworth et al., 1978). It has not been evaluated for fungistatic activity in Palm Kernel Cake. The data relative to the safety of sorbic acid established by numerous long term feeding experiments with rats has been reviewed by Gaunt et al., (1975).

Dilworth et al., (1978) found that dietary addition of sorbic acid (0.02%, 0.04%, 0.06%) numerically improved broiler growth rate which were not affected by the dietary addition of either gelatin violet (0.05%) or calcium propionate (0.10%). They also reported that optimum dietary level of 0.04% sorbic acid as feed preservative appears to be adequate in increasinng broiler performance when broilers are exposed to fungal metabolites. Suwathep et al., (1981) reported that addition of sorbic acid as a mould inhibitor at level of 0.025% in high moisture (14-15%) diets for starter and grower broiler chicks significantly improved ($P < 0.05$) feed conversion without any effect on daily weight gain. Mortality of chicks was also found to decrease ($P < 0.05$) with the treatment.

## 3. MATERIALS AND METHODS

Fresh palm kernel cake expeller (PKC) used for this experiment was obtained from the Lee Oil Mills Sdn. Berhad, Kelang, Selangor on the 29th May 1984. The by-products was analysed to contain 7.51% moisture, 15.72% crude protein, 13.05% crude fat, 19.62% crude fibre, 3.65% ash and 4.95 Mcal/kg. gross energy. Amino acids composition of the PKC used in the experiment is illustrated in Appendix 7.

## 3.1 Preparation and Samping Procedures

Sample was divided randomly into seven batches of 40 kg. each. One batch was used as control and the others were treated with different levels of Santoquin (Mosanto Chemical Ltd.) at 100, 175 and 250 ppm, Aflaban (Mosanto Chemical Ltd.) at 200 ppm, the mixture of Santoquin and Aflaban at 175 and 200 ppm respectively or oven dried at 60$^{o}$C for 48 hours. Premixing was conducted with Kenwood Major Homogeniser at 150 rpm for 15 minutes. Samples were then mixed using Horizontal Rotary Feed Mixer at 52 rpm for 30 minutes. Ten kilograms of PKC for each treatment combination were kept in duplicate in double-layer plastic bag and gunny sack except for the oven dried PKC where the sample was only kept in plastic bag. Plastic bag samples were tied and kept in double-layer brown paper bag. All samples were stored at room temperature. Treatments and zero day sampling were conducted within 24 hours of factory production. Two hundred grams of sample were collected from each bag at 0,7, 14 and 28 day incubation intervals. Several randomised samples were collected vertically from top to the base of the bag by using a 2.2 cm diameter glass tube. The samples were then kept in a small sealed plastic bag.

## 3.2 Extraction Procedure

Oil was obtained from the samples by modified soxhlet extraction (AOAC, 1980), and due to limitation of facility, fat extraction was done immediately for the first 14 samples while the remaining 12 samples were kept in the freezer below -10°C. This latter set of samples were extracted on the following day.

Ninety gram sample from each treatment was extracted with petroleum ether (b.p. 40-60°C) at 50°C for 12 hours. Residue of petroleum ether was evaporated initially by Rotary Evaporator for 15 minutes. The PKC oil was then kept in the oven at 50°C for another hour. The oil samples were kept in the freezer below -10°C prior to chemical analysis.

## 3.3 Chemical Analysis

Acidity and anisidine value were determined by the IUPAC reference methods (Method II DI and II D26 respectively). Peroxide value was analysed following the AOCS Official Methods Cd 8-53 and totox value was obtained by adding two time the peroxide value and the corresponding anisidine value (Cornelius, 1977). Chemical composition of PKC was determined following procedures as outlined by AOAC (1980). The amino acid content of PKC was determined by hydrolysis and column chromatography according to the method described by Moore and Stein (1951).

## 3.4 Statistical Analysis

Statistical analysgis of the data were conducted considering the treatments were split-plot in nature and were processed using general linear model by computer programs of Statistical Analysis System (SAS). Duncan's multiple range test was used where necessary to determine significant difference between the treatment means. Data was analysed according to the diagram illustrated in Figure 2.

TREATMENTS

| PLASTIC AND GUNNY SACK | PLASTIC AND GUNNY SACK |
|---|---|
| EXPERIMENT I | EXPERIMENT II |
| 1. Control[ab] | 1. Control[ab] |
| 2. Santoquin at 100 ppm | 2. Santoquin at 175 ppm[ab] |
| 3. Santoquin at 175 ppm[ab] | 3. Aflaban at 200 ppm |
| 4. Santoquin at 250 ppm | 4. Combination of 2 + 3 |

PLASTIC
BAG

EXPERIMENT III

1. Control[a]
2. Santoquin at 175 ppm[a]
3. Aflaban at 200 ppm[a]
4. Combination at 2 + 3[a]
5. Oven dry

Figure 2: Statistical Analysis of the Data for Various Treatments as a Comparative Study

[ab] Sample with similar data was analysed differently

[a] Data were extracted from samples kept in plastic bag only.

# 4. RESULTS

## 4.1 Experiment 1

The effect of different levels of Santoquin (100, 175 and 250 ppm), packaging materials and incubating periods on hydrolytic and oxidative rancidity of PKC stored at room temperature.

### 4.1.1 Hydrolytic rancidity

Free fatty acids production data are presented in Appendix 8. Acidity of control and Santoquin treated PKC were significantly increase ($P < 0.01$) during storage from an average of 5.19% to 5.52%, 6.46% and 6.63% on the day 0,7,14 and 28 respectively. Addition of Santoquin at 250 ppm significantly reduced ($P < 0.01$) FFA production. However, Santoquin at 100 and 175 ppm slightly increased FFA formation (Appendix II). Plastic bag is found to have better effect in inhibiting hydrolytic rancidity of PKC when compared to gunny sack (5.40% vs 5.50% respectively).

### 4.1.2 Oxidative rancidity

#### 4.1.2.1 Peroxide value.

Primary oxidation of control and Santoquin treated PKC were significantly increased ($P < 0.01$) during storage (Appendix 8). Peroxide value was sharply elevated during the first 7 days of storage and reduced after this from an average of 1.36 meq/kg to 2.21, 2.12 and 1.74 meq/kg during day 0,7,14 and 28 respectively. The effect of Santoquin in inhibiting peroxide production is shown in Table 1. PKC receiving Santoquin at 100, 175 and 250 ppm treatment level obtained a peroxide value range of 1.50, 1.55 and 1.36 meq/kg respectively. Changing pattern of peroxide value in PKC treated with different levels of Santoquin is illustrated in

(Appendix 12). No significant effect from packaging materials were found.

4.1.2.2 Anisidine Value

Secondary oxidation of control and Santoquin treated PKC was significantly increased ($P < 0.01$) from an average of 10.55 to 14.50, 16.67 and 18.90 on the 0,7,14 and 28 days of storage respectively. Addition of Santoquin at 100, 175 and 250 ppm significantly reduced ($P < 0.01$) anisidine value (Table 1). Samples kept in plastic bags are found to have lower anisidine value when compared to those from gunny sacks (13.60 vs 16.71 ppm). Santoquin at 250 ppm has superior reduction effect on secondary oxidation followed by Santoquin at 175 and 100 ppm levels respectively (Appendix 13).

4.1.2.3 Totox value

Oxidative rancidity of control and Santoquin treated PKC were significantly increased ($P < 0.01$) during incubation from an average of 13.27 to 18.91, 20.91 and 22.38 on day 0,7,14 and 28 respectively. Totox value was significantly reduced ($P < 0.01$) from 29.74 in the control to 18.35, 15.14 and 12.26 in PKC samples treated with 100, 175 and 250 ppm Santoquin respectively. PKC kept in plastic bags obtained a lower totox value than those kept in the gunny sacks (17.34 vs 20.40)

Table 1: Means of acidity, peroxide, anisidine and totox values of PKC at different Santoquin levels, packaging materials and incubation periods

| Variable | Santoquin (ppm) | | | | Packaging materials | | Incubation Periods (days) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 100 | 175 | 250 | Plastic | Gunny | 0 | 7 | 14 | 28 |
| Acidity (% FFA) | $5.48^{b}$ | $5.55^{a}$ | $5.58^{a}$ | $5.19^{c}$ | $5.40^{b}$ | $5.50^{a}$ | $5.19^{d}$ | $5.52^{c}$ | $6.46^{b}$ | $6.63^{a}$ |
| Peroxide Value (meq/kg) | $3.02^{a}$ | $1.50^{b}$ | $1.55^{b}$ | $1.36^{c}$ | $1.87^{a}$ | $1.85^{a}$ | $1.36^{d}$ | $2.21^{a}$ | $2.12^{b}$ | $1.74^{c}$ |
| Anisidine Value | $23.70^{a}$ | $15.34^{b}$ | $12.03^{c}$ | $9.54^{d}$ | $13.60^{b}$ | $16.71^{a}$ | $10.55^{d}$ | $14.50^{c}$ | $16.67^{b}$ | $18.90^{a}$ |
| Totox Value | $29.74^{a}$ | $18.35^{b}$ | $15.14^{c}$ | $12.26^{d}$ | $17.34^{b}$ | $20.40^{a}$ | $13.27^{d}$ | $18.91^{c}$ | $20.91^{b}$ | $22.38^{a}$ |

[a,b,c,d] Means in the same row within each main treatment effect bearing different superscript differ significantly at $P < 0.05$.

## 4.2 Experiment 2

The effect of Santoquin, Aflaban, combination of Santoquin and Aflaban, packaging materials and incubation periods on hydrolytic and oxidative rancidity of PKC stored at room temperature.

### 4.2.1. Hydrolytic Rancidity

The effect of Aflaban in reducing FFA production is shown in Appendix 9. Santoquin together with Aflaban provide similar effect ($P < 0.05$) in reducing FFA production when compared to Aflaban alone (3.73% vs 3.77% respectively). The pattern of effect of treatments and incubation period on hydrolytic rancidity of PKC are as illustrated in (Appendix 11). It is found that during 28 days of incubation PKC samples kept in plastic bag have significantly lower ($P < 0.01$) FFA formation when compared to those kept in gunny sack (4.61% vs 4.67% respectively).

### 4.2.2. Oxidative Rancidity

#### 4.2.2.1 Peroxide value

Aflaban inhibited ($P < 0.01$) peroxide formation at lower rate when compared to Santoquin (1.89 vs 1.55 meq/kg respectively). Combination of these two substances gave the most effective inhibition action (Table 2). Peroxide formation for various types of treatment sharply rose from 1.36 to 2.28 meq/kg on day 0 to 7 respectively, then declined to 2.21 and 1.80 meq/kg on day 14 and 28 respectively.

#### 4.2.2.2 Anisidine Value

Addition of Aflaban, Santoquin and their combination on PKC significantly ($P < 0.01$) reduced secondary oxidation process

Table 2: Means of acidity, peroxide, anisidine and totox value of PKC at different treatments, packaging materials and incubation periods

| Variable | Treatments | | | | Packaging materials | | Incubation Periods (days) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Santoquin | Aflaban | Santoquin + Aflaban | Plastic | Gunny | 0 | 7 | 14 | 28 |
| Acidity (% FFA) | 5.46[b] | 5.58[a] | 3.77[c] | 3.73[c] | 4.61[b] | 4.67[a] | 3.19[c] | 4.46[b] | 5.46[a] | 5.45[a] |
| Peroxide Value (meq/kg) | 3.02[a] | 1.55[c] | 1.89[b] | 1.30[d] | 1.98[a] | 1.90[b] | 1.36[d] | 2.38[a] | 2.21[b] | 1.80[c] |
| Anisidine Value | 23.70[a] | 12.03[c] | 12.78[b] | 10.14[d] | 13.67[b] | 15.66[a] | 10.55[c] | 15.42[b] | 15.49[b] | 17.20[a] |
| Totox Value | 29.74[a] | 15.14[c] | 16.56[b] | 12.75[d] | 17.63[b] | 19.40[a] | 13.27[c] | 20.19[b] | 19.92[b] | 20.81[a] |

[a,b,c,d] Means in the same row within each main treatment effects bearing different superscript differ significantly at $P < 0.05$.

from 23.70 on untreated samples to 12.74, 12.03 and 10.14 on the three respective treatments. Plastic bag seemed to have better inhibition effect ($P < 0.01$) on secondary oxidation of PKC when compared to gunny sack (13.67 vs 15.66 respectively). The pattern of effect of treatments on incubation is illustrated in Appendix 13.

#### 4.2.2.3 Totox value

Oxidative rancidity of control and treated PKC for various treatments significantly increased during incubations from and average of 13.27 to 20.19, 19.92 and 20.81 on day 0,7,14 and 28 respectively. It is found that the combination of Santoquin and Aflaban give the best inhibition effect on oxidative value followed by Santoquin and Aflaban alone (averaged 12.75, 15.14 and 16.56 respectively). Plastic bag seemed to provide better inhibition effect on oxidative process when compared to gunny sack (Appendix 14). When compared to Santoquin, Aflaban tended to have better effect in reducing oxidative process when both samples were kept in gunny bag.

## 4.3 Experiment 3.

The effect of Santoquin, Aflaban, combination of Aflaban and Santoquin, oven dry and incubation periods on hydrolytic and oxidative rancidity of PKC stored in plastic bag at room temperature

### 4.3.1. Hydrolytic Rancidity

The formation of FFA was significantly increased ($P < 0.01$) during the storage with all types of treatment (Appendix 10). Oven dry provided the most inhibition effect ($P < 0.01$). During 28 days of incubation FFA formation was significantly reduced from an average of 5.44% in the control to 3.77%, 3.70% and 3.07% on samples treated with Aflaban at 200 ppm, the mixture of Santoquin at 175 ppm and Aflaban at 200 ppm and oven dry treatment respectively.

4.3.2. Oxidative Rancidity

4.3.2.1 Peroxide Value

The effect of primary oxidation is illustrated in Appendix 10. Over 28 day incubation, oven drying provided better inhibition effect on peroxide formation compared to Santoquin and Aflaban (1.42 meq/kg vs 1.56 and 1.91 meq/kg respectively). However, the mixture of Santoquin and Aflaban gave the most effective inhibition effect (1.34 meq/kg).

4.3.2.2 Anisidine Value

During incubation, anisidine value in PKC receiving various treatments increased from an average of 10.55 to 12.45, 11.74 and 12.40 on day 0,7,14 and 28 respectively. Among the treatments oven dry samples provided the best inhibition effect on secondary oxidation of PKC (Table 3). As illustrated in Appendix 13 anisidine value in PKC receiving oven dry treatment decreased from an average of 10.55 to 2.62, 2.89 and 0.92 on day 0,7,14 and 28 respectively.

4.3.2.3 Totox value

Rate of oxidative rancidity of PKC during 28 days of storage was significantly reduced from an average of 30.22 in the control of 16.55, 12.75, 11.01 and 7.08 in PKC samples treated with Santoquin, Aflaban, mixture of Aflaban and Santoquin and oven dry, respectively. Oxidative value of oven dry samples was observed to be 13.27 on day 0 then changed to 4.98, 5.66 and 4.42 on day 7,14 and 28 respectively (Appendix 14). Oven dry provided the best inhibition effect on oxidative rancidity of PKC compared to other treatments.

# 5. DISCUSSION

## 5.1 Hydrolytic and Oxidative Rancidity of Untreated PKC

Hydrolytic and oxidative rancidity of untreated PKC increased during storage. There is significant difference ($P < 0.01$) on the effect of packaging materials on rancidity of PKC during incubation. It is found that plastic bag has better inhibition effect on the formation of FFA and on reducing oxidative rancidity when compared to the gunny sack (Appendix 15). Free fatty acids production rises very rapidly during the first 14 days of incubation and the rate of production declines thereafter. Similar result was observed on primary oxidation during the first 7 days of storage. The process reaches a maximum on day 7, then declines slowly thereafter. It is clear that acidity and peroxide value do not give a good picture on the correlation of hydrolytic and oxidative rancidity of PKC during storage except during the very first few days. Similar result was observed by Jacobsberg (1973) on the palm oil. The decline of peroxide value after 7 days of incubation indicated the conversion of peroxide into secondary oxidative product.

The interaction of primary and secondary oxidation of PKC was clearly shown in Appendix 15. Both peroxide and anisidine values were sharply elevated during the first 7 days of incubation. When peroxide value started to decline from day 7 onwards, the

Table 3: Means of acidity, peroxide, anisidine and totox value of PKC at different treatments, packaging materials and incubation periods

| Variable | Treatments | | | | | Incubation Periods (days) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Control | Santoquin | Aflaban | Santoquin + Aflaban | Oven | 0 | 7 | 14 | 28 |
| Acidity (% FFA) | 5.44[b] | 5.51[a] | 3.77[c] | 3.70[d] | 3.07[e] | 3.19[d] | 4.11[c] | 4.92[b] | 4.97[a] |
| Peroxide Value (meq/kg) | 3.12[a] | 1.56[c] | 1.91[b] | 1.34[e] | 1.42[a] | 1.36[c] | 2.17[a] | 2.12[a] | 1.83[b] |
| Anisidine Value | 23.99[a] | 7.89[d] | 12.74[b] | 10.07[c] | 4.24[e] | 10.55[c] | 12.45[a] | 11.74[b] | 12.40[a] |
| Totox Value | 30.22[a] | 11.01[d] | 16.55[b] | 12.75[c] | 7.08[e] | 13.27[c] | 16.78[a] | 15.98[b] | 16.06[b] |

[a,b,c,d,e] Means in the same row within each main treatment effects bearing different superscript differ significantly at $P < 0.05$.

anisidine value continues to increase. Hence, the combination effect of both oxidative process by using totox value give a clearer picture of the progress of oxidation (Cornelius, 1977).

The correlation of FFA production and oxidative value was clearly shown during the first 14 days of incubation. Totox value was found to increase with the increase in FFA production. Jacobsberg and Canamunoz et al., (1976) reported that FFA produced in palm oil increased its oxidative value sharply by increasing the solubility of iron metal which is an active catalyst of the oxidative process. Planter (1979) reported that through the action of FFA and the presence of pro-oxidants such as metals, the rate at which oxygen is absorbed by oil is markedly accelerated. However, Catalano and Felice (1970) believed that FFA may directly act on the oxidative process of the oil. According to this latter group of researchers, FFA catalyses the autoxidation of triglycerides at concentration of 0.5% and above via their carbonyl groups.

5.2 Effect of Antioxidant

Santoquin added to PKC retarded oxidative deterioration during storage by controlling the progressive built up of hydroperoxide and secondary oxidative products (Appendix 12, 13 and 16). Kirklands and Fuller (1969, 1970) reported that Santoquin delayed chemical reactions associated with distruction of unsaturated fatty acids, phospholipids and triglycerids and formation of secondary oxidation product. The presence study shows that oxidative rancidity of PKC was significantly retarded by 50.3% or 48.7%, 55.0% (estimated by peroxide value), 35.3%, 49.2%, 59.7%

(estimated by anisidine value) and 38.3%, 49.1%, 58.8% (estimated by totox value) during 28 days of storage, when 100, 175 and 250 ppm of Santoquin was added respectively. It is apparent that the effectiveness of Santoquin in providing protection to PKC stored at room temperature increases with increasing levels of Santoquin from 100 to 175 and 250 ppm. The optimum effect of Santoquin in inhibiting rancidity has been reported to be between 186 and 200 ppm in grass meal (Dvinskeja 1969) and 200 ppm in fish meal (Chahine, 1978). However, Kratzer and Payne((1976) reported that FFA production in rice bran was unaffected by the presence of Santoquin up to 300 ppm level. This study provide an evidence that Santoquin at 250 ppm significantly reduced the rate of FFA formation during 28 days of incubation.

5.3 Effect of Fungistatic Agents

The effect of microbial liplysis in increaseing FFA in Palm Kernel has been reported by Turner (1969, 1971). Heaton et al., (1975) also observed that high level of FFA in safflower seeds were due to lipolytic action of moulds. Similar results were also obtained on coconut oil (Hoover, 1973), cotton seed oil and sunflower seeds (Zimmer, 1975). According to Takigawa (1976) as moulds grow rapidly, crude fat decreased and FFA was formed.

Aflaban has been shown to inhibit growth of a wide variety of microorganisms, including moulds, yeasts and bacteria in animal feeds. It was also found to be effective in inhibiting oxidative rancidity. Addition of Aflaban at 200 ppm on PKC significantly educed ($P < 0.01$) the percentage of FFA production by 31.2% during the 28 days of storage (Appendix 17). Peroxide, anisidine and tolox values were significantly reduced ($P < 0.01$) by 37.4%, 46.1% and 57.2% respectively by the addition of Aflaban at 200 ppm at 28 days of storage. The role of Aflaban in reducing the rate of oxidative rancidity was not known. It could be due to indirect effect by inhibiting FFA production (Jacobsberg, 1974; Canomunoz et al., 1976)

## 5.4 Effect of Combination of Aflaban and Santoquin

Hydrolytic and oxidative rancidity of PKC was significantly inhibited ($P < 0.01$) by the combine addition of Santoquin and Aflaban at 175 and 200 ppm respectively. As illustrated in Appendix 17, the mixture of these two substances reduced FFA production at the same magnitude when Aflaban alone was used. This shows that FFA formation was unaffected by the presence of Santoquin at 175 ppm. Similar finding has been reported by Kratzer and Payne (1976) on rice bran. On oxidation process this combination significantly reduced peroxide, anisidine and tolox values by 57.0%, 57.2% and 57.1% respectively during 28 days of storage. Combination of Santoquin and Aflaban has better effect on inhibition of oxidative rancidity when compared to Santoquin or Aflaban alone.

## 5.5 Effect of Packaging Materials.

Lipid oxidation was accelerated by the presence of light (especially ultraviolet or near ultraviolet) and aeration (Lea, 1964,; Sherwin, 1980). The ability of plastic bag to inhibit these two factors on storage of PKC was significantly shown when compared to gunny sack. Anisidine and totox values were significantly reduced by 18.6% and 15.0% in Experiment 1 and 12.7% and 9.4% in Experiment 2 respectively when samples were kept in plastic bags compared to those kept in gunny sack (Appendix 18). Samples kept in plastic bag in Experiment 2 obtained a significantly higher peroxide value. This is an indication of the higher rate of peroxide breakdown in PKC when kept in gunny sack. The effect of packaging materials on FFA production was significantly shown (Appendix 18). Plastic bag has better inhibition effect on FFA formation when compared to gunny sack. The effect of plastic bag on hydrolytic rancidity was not clear. It could be due to the combination effect of restriction of light, aeration or moisture during storage (Lea, 1964).

## 5.6 Effect of Dehydration and Heat Treatment

Oven dry treatment significantly reduced ($P < 0.01$) FFA production of PKC during storage. It provides better inhibition effect on FFA formation when compared to Aflaban (43.6% vs 30.7%). The treatment process employed in this experiment reduced moisture content to 0.67% and at the same time, according to Bek-Nielsen (1976) destroyed lipase activity in PKC. Enzymic lipolysis and chemical lipolysis due to the presence of water are among the factors that was responsible for accelerating FFA production (Bek-Nielsen, 1976; Dessasis, 1957). Kratzer and Payne (1976) reported that autoclaving or paraboiling reduced the rate of hydrolysis in rice bran.

The present study also found that oven dry has a better inhibition effect on oxidative rancidity of PKC when compared to Santoquin or mixture of Santoquin and Aflaban (76.6% vs 63.6% or 57.2% respectively) during 28 days of storage (Appendix 19). Bek-Nielsen (1969) suggested that moisture in palm oil at a level about 1.0% appears to act as inhibitor to the oxidation process. This was possible as moisture formed a barrier between oil and oxygen in the dissolved air. Labuza et al., (1971) believed that the antioxidant effect of water is due primarily to the hydration of the metal catalyst, where at high moisture content oxidation process was accelerated through its solvent activity. The higher effectiveness of heat treatment in controlling the development of rancidity than Santoquin up to 300 ppm level on rice bran was also recognised by Kratzer and Payne (1976).

## 6. CONCLUSION

The quality of Palm Kernal Cake Expeller Press (PKC) was significantly reduced during storage. Rancidity was observed within seven days of incubation at room temperature. Addition of Santoquin, Aflaban, combination of Santoquin and Aflaban, dehydration and heat treatment significantly improved the storage quality. However, only PKC trated with Aflaban at 200 ppm, mixture of Santoquin at 175 ppm and Aflaban at 200 ppm, dehydration and heat treatment significantly inhibited hydrolytic rancidity to within the range of current commercial specification for palm kernels (maximum at 4.75% FFA as lauric acid) during 28 days of storage. This pattern of effect is the same whether the treated PKC was kept in plastic bag or gunny sack.

Oxidative rancidity of PKC was significantly inhibited to within the standard specification (Totox value maximum at 15, using crude palm oil as the reference) with addition of Santoquin at 175 and 250 ppm, combination of Santoquin at 175 ppm and Aflaban 200 ppm and dehydration and heat treatment of PKC during 28 days of storage when it is kept either in plastic bag or gunny sack. However, plastic bags have better effect in maintaining the quality of PKC during storage when compared to gunny sack.

It is concluded that PKC should betreated with the combination of Santoquin and Aflaban at 175 and 200 ppm respectively or dehydration and heat treatment, then kept in plastic bag is the most effective method in preserving the quality of PKC during storage.

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## APPENDIX 1

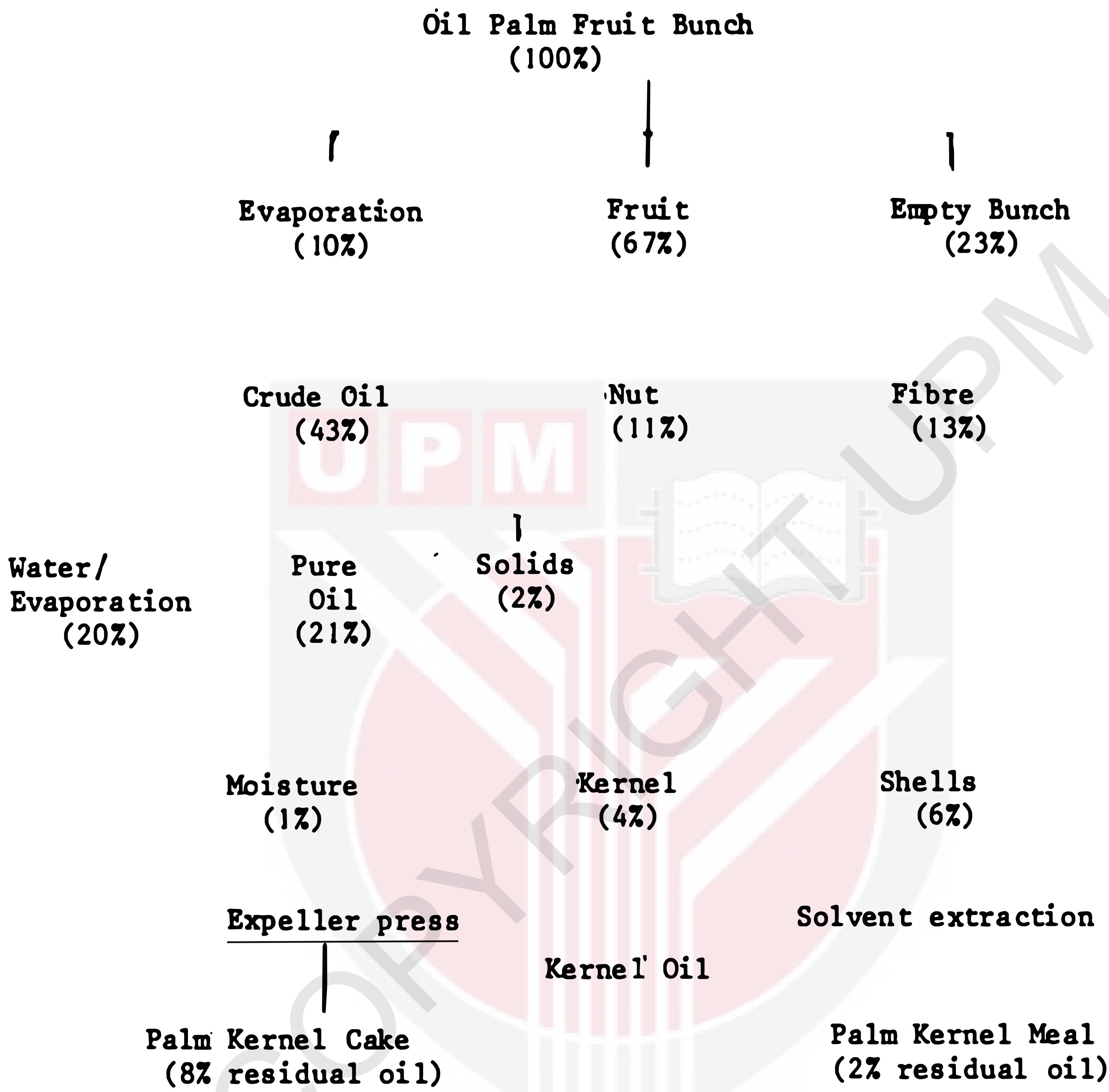



Figure 3: Production chart of the Palm Oil Industry

Source: Ganabathi, S. (1983)

# APPENDIX 2

Table 4: Chemical composition of PKC

| Consituent | PKC Expeller Press |
|---|---|
| Moisture (%) | 10.00 |
| Crude protein (%) | 14.50 |
| Crude fibre (%) | 14.20 |
| Ether extract (%) | 8.00 |
| Ash (%) | 4.00 |
| Calcium (%) | 0.26 |
| Phosphorus (%) | 0.71 |
| Magnesium (%) | 0.24 |
| Fe (ppm) | 40.50 |
| Cu (ppm) | 28.50 |
| Zn (ppm) | 77.00 |
| Mn (ppm) | 225.00 |
| Gross energy (kcal/kg) | 3728.00 |

Source: Yeong, 1982; McDonald, 1973.

APPENDIX 3

Table 5: Composition of Fatty Acids on Palm Kernel Oil

| Fatty acids | Malaysian Palm Kernel Oil (% by wt.) |
|---|---|
| **A. Saturated Fatty Acids** | |
| 1. Caproic ($C_5H_{11}COOH$) | 0.2 |
| 2. Caprylic ($C_7H_{15}COOH$) | 3.6 |
| 3. Capric ($C_9H_{19}COOH$) | 3.4 |
| 4. Lauric ($C_{11}H_{23}COOH$) | 47.4 |
| 5. Myristic ($C_{13}H_{27}COOH$) | 15.6 |
| 6. Palmitic ($C_{15}H_{31}COOH$) | 8.9 |
| 7. Stearic ($C_{17}H_{35}COOH$) | 2.1 |
| **B. Unsaturated Fatty Acids** | |
| 1. Oleic ($C_{17}H_{33}COOH$ or $C_{18}$ ) | 16.7 |
| 2. Linoleic ($C_{17}H_{31}COOH$ or $C_{18}^{9,12}$) | 2.0 |

Source: Rossell, 1975.

## APPENDIX 4

Dimers, higher polymers

Polymerization

FAT HYDROPEROXIDE

Further oxidation

Fission

Dehydration

Oxidation of CH = CH in other molecules

Diperoxides

Aldehydes
semi-aldehydes
aldehydo-glycerides
OH - compounds

Keto-Glyceride

Epoxides
OH - glycerides
Di OH-glycerides

Polymers

Acids

Figure 4: Some routes of decomposition of fat hydroperoxide

Source: Lea, C.H. (1962)

# APPENDIX 5

UNSATURATED FAT + OXYGEN

Lipoperoxides,
aldehydes,
acids,
keto-, hydroxy-
and epoxy compound,
polymers.

Cause:

Off odours and flavours,
destruction of essential fatty acids
'browning' reaction with protein etc.,
and possible toxicity

Coupled oxidation

Cause:

Destruction of aroma
and flavour constituen
pigments, vitamins.

Figure 5: Effect of lipid oxidation

Source: Lea, C.H. (1962).

# APPENDIX 6

Table 6: Factors influencing the rate and cause of lipid oxidation

| Accelerating factor | Inhibiting factor |
| --- | --- |
| i. High temperature | Refrigeration |
| ii. Light (uv)<br>Ionizing radiation | Opaque or wrappers<br>or coloured containers. |
| iii. Peroxides (including oxidised fats) | Exclusion of oxygen |
| iv. Lipoxidase enzyme | Blanching |
| v. Organic iron catalysts (hemoglobin, etc) | Antioxidants |
| vi. Trace metal catalysts (Cu, Fe, etc.) | Metal deactivators |

Source: Lea, C.H. (1962)

APPENDIX 7

Table 7: Amino Acids contents of Palm Kernel Cake.

| Amino acid | mg. per g of protein |
|---|---|
| Glutamic acid | 193.33 |
| Arginine | 108.77 |
| Aspartic acid | 85.01 |
| Leucine | 62.04 |
| Glycine | 50.73 |
| Alanine | 47.66 |
| Valine | 44.55 |
| Serine | 41.51 |
| Lysine | 31.45 |
| Isoleusine | 26.05 |
| Threonine | 25.96 |
| Proline | 24.68 |
| Tryosine | 19.78 |
| Histidine | 18.19 |

**Table 8** The effect of different levels of Santoquin , packaging materials and incubation periods on hydrolytic and oxidative rancidity of PKC stored at room temperature.

| TREATMENTS | | | CHEMICAL ASSESSMENT OF RANCIDITY | | | |
|---|---|---|---|---|---|---|
| Santoquin ( ppm ) | Packaging Material | Incubation Period (days) | Acidity[a] | Peroxide Value[b] | Anisidine Value[c] | Totox Value[d] |
| | | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | Plastic | 7 | 5.45 ± 0.05 | 3.86 ± 0.01 | 21.77 ± 1.30 | 29.49 ± 1.27 |
| | bags | 14 | 6.97 ± 0.05 | 3.77 ± 0.02 | 29.49 ± 0.51 | 37.02 ± 0.47 |
| | | 28 | 6.18 ± 0.02 | 3.49 ± 0.16 | 34.13 ± 0.00 | 41.11 ± 0.31 |
| 0 | | | | | | |
| | | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | | 7 | 5.53 ± 0.08 | 3.57 ± 0.04 | 20.26 ± 1.51 | 27.40 ± 1.60 |
| | | | 7.03 ± 0.11 | 3.56 ± 0.03 | 29.28 ± 0.20 | 36.40 ± 0.14 |
| | | 28 | 6.29 ± 0.01 | 3.18 ± 0.29 | 33.60 ± 0.03 | 39.95 ± 0.55 |
| | | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | Plastic | 7 | 5.46 ± 0.06 | 1.76 ± 0.23 | 14.63 ± 0.64 | 18.14 ± 1.10 |
| | bags | 14 | 7.02 ± 0.17 | 1.39 ± 0.00 | 17.07 ± 2.11 | 19.85 ± 2.11 |
| | | 28 | 6.39 ± 0.04 | 1.38 ± 0.01 | 19.64 ± 1.67 | 22.39 ± 1.18 |
| 100 | | | | | | |
| | | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | Gunny | 7 | 5.50 ± 0.04 | 1.71 ± 0.04 | 14.77 ± 0.96 | 18.18 ± 0.89 |
| | sacks | 14 | 6.99 ± 0.18 | 1.59 ± 0.00 | 16.33 ± 0.67 | 19.51 ± 0.67 |
| | | 28 | 6.70 ± 0.01 | 1.49 ± 0.15 | 19.20 ± 0.72 | 22.17 ± 0.42 |
| | | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | Plastic | 7 | 5.53 ± 0.08 | 1.99 ± 0.07 | 9.02 ± 0.25 | 13.00 ± 0.39 |
| | bags | 14 | 6.58 ± 0.02 | 1.74 ± 0.00 | 6.24 ± 0.42 | 9.72 ± 0.42 |
| | | 28 | 6.76 ± 0.07 | 1.15 ± 0.04 | 5.77 ± 0.10 | 8.06 ± 0.17 |
| 175 | | | | | | |
| | | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | Gunny | 7 | 5.57 ± 0.08 | 2.16 ± 0.02 | 14.64 ± 1.00 | 18.95 ± 0.95 |
| | sacks | 14 | 6.68 ± 0.04 | 1.49 ± 0.12 | 16.95 ± 0.23 | 19.92 ± 0.47 |
| | | 28 | 7.17 ± 0.01 | 1.18 ± 0.01 | 22.56 ± 1.57 | 24.92 ± 1.54 |
| | | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | Plastic | 7 | 5.43 ± 0.18 | 1.19 ± 0.08 | 8.04 ± 1.34 | 10.41 ± 1.19 |
| | bags | 14 | 5.85 ± 0.01 | 1.77 ± 0.04 | 6.34 ± 0.08 | 9.92 ± 0.11 |
| | | 28 | 6.03 ± 0.09 | 1.00 ± 0.00 | 3.30 ± 0.35 | 5.30 ± 0.35 |
| 250 | | | | | | |
| | | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | Gunny | 7 | 5.67 ± 0.09 | 1.45 ± 0.04 | 12.87 ± 0.22 | 15.76 ± 0.29 |
| | sacks | 14 | 5.96 ± 0.22 | 1.66 ± 0.08 | 11.68 ± 1.43 | 14.99 ± 1.58 |
| | | 28 | 6.19 ± 0.04 | 1.08 ± 0.11 | 13.00 ± 2.60 | 15.15 ± 2.39 |

| Variables : | STATISTICAL SIGNIFICANCE | | | |
|---|---|---|---|---|
| Santoquin | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Material | $P < 0.01$ | $P > 0.10$ | $P < 0.01$ | $P < 0.01$ |
| Santoquin * Material | $P > 0.10$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Incubation | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Santoquin * Incubation | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Material * Incubation | $P < 0.01$ | $P > 0.10$ | $P < 0.01$ | $P < 0.01$ |
| Santoquin * Material * Incubation | $P > 0.10$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |

Mean errors quoted are means of duplicate samples.

[a] is a conversional expression of the % of FFA expressed as Lauric acid.

[b] Milliequivalents of peroxide per 1000 grams of sample ( meq/kg oil ).

[c] defined as 100 times the optical density in a solution containing 1 gram of oil in 100 ml of a mixture solvent and anisidine.

APPENDIX 9

Table 9 : The effect of different types of treatments, packaging materials and incubation periods on hydrolytic and oxidative rancidity of PKC stored at room temperature.

| TREATMENTS | | | CHEMICAL ASSESSMENT OF RANCIDITY | | | |
|---|---|---|---|---|---|---|
| Treatment ( ppm ) | Packaging Material | Incubation Period (days) | Acidity[a] | Peroxide Value[b] | Anisidine Value | Totox Value |
| Control | Plastic bags | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | | 7 | 5.45 ± 0.05 | 3.86 ± 0.01 | 21.77 ± 1.30 | 29.49 ± 1.27 |
| | | | 6.97 ± 0.05 | 3.77 ± 0.02 | 29.49 ± 0.51 | 37.02 ± 0.47 |
| | | | 6.18 + 0.02 | 3.49 ± 0.1 | 34.13 ± 0.00 | 41.11 ± 0.31 |
| | sacks | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | | 7 | 5.53 ± 0.08 | 3.57 ± 0.04 | 20.26 + 1.51 | 27.40 ± 1.60 |
| | | 14 | 7.03 ± 0.11 | 3.56 ± 0.03 | 29.28 ± 0.20 | 36.40 ± 0.14 |
| | | 28 | 6.29 ± 0.01 | 3.18 ± 0.29 | 33.60 ± 0.03 | 39.95 ± 0.55 |
| Santoquin ( 175 ) | Plastic bags | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | | 7 | 5.53 ± 0.08 | 1.99 ± 0.07 | 9.02 ± 0.25 | 13.00 ± 0.39 |
| | | | 6.58 ± 0.02 | 1.74 ± 0.00 | 6.24 ± 0.42 | 9.72 ± 0.42 |
| | | | 6.76 ± 0.07 | 1.15 ± 0.04 | 5.77 ± 0.10 | 8.06 ± 0.17 |
| | Gunny sacks | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | | 7 | 5.57 ± 0.08 | 2.16 ± 0.02 | 14.64 ± 1.00 | 18.95 ± 0.95 |
| | | 14 | 6.68 ± 0.04 | 1.49 ± 0.12 | 16.95 ± 0.23 | 19.72 ± 0.47 |
| Aflaban ( 200 ) | Plastic bags | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | | 7 | 3.32 ± 0.04 | 2.51 ± 0.08 | 17.09 ± 0.14 | 22.10 ± 0.01 |
| | | 14 | 4.18 ± 0.04 | 2.13 ± 0.01 | 11.95 ± 0.10 | 16.31 ± 0.13 |
| | | 28 | 4.37 ± 0.06 | 1.58 ± 0.01 | 11.36 ± 0.09 | 14.51 ± 0.11 |
| | Gunny sacks | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | | 7 | 3.32 ± 0.14 | 2.41 ± 0.08 | 16.84 ± 1.97 | 21.65 ± 1.81 |
| | | 14 | 4.14 ± 0.06 | 2.06 ± 0.13 | 12.93 ± 0.76 | 17.04 ± 0.49 |
| | | 28 | 4.45 ± 0.08 | 1.67 ± 0.11 | 11.01 ± 0.76 | 14.34 ± 0.55 |
| Santoquin (175) + Aflaban (200) | Plastic bags | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.01 | 13.27 ± 0.00 |
| | | 7 | 3.45 ± 0.01 | 1.29 ± 0.08 | 11.78 ± 0.87 | 14.36 ± 0.70 |
| | | 14 | 3.99 + 0.10 | 1.54 ± 0.08 | 8.13 ± 0.60 | 11.20 ± 0.76 |
| | | 28 | 4.18 ± 0.01 | 1.18 ± 0.00 | 9.82 ± 0.25 | 12.18 ± 0.25 |
| | Gunny sacks | 0 | 3.19 + 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| | | 7 | 3.49 ± 0.08 | 1.28 ± 0.01 | 12.01 ± 0.54 | 14.57 ± 0.51 |
| | | 14 | 4.13 ± 0.18 | 1.39 + 0.00 | 8.96 + 0.53 | 11.74 ± 0.53 |
| | | 28 | 4.22 ± 0.12 | 1.03 ± 0.12 | 9.34 ± 0.47 | 11.39 ± 0.71 |

| Variables : | STATISTICAL SIGNIFICANCE | | | |
|---|---|---|---|---|
| Treatment | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Material | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Treatment * Material | $P = 0.08$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Incubation | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Treatment * Incubation | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Material * Incubation | $P = 0.02$ | $P = 0.02$ | $P < 0.01$ | $P < 0.01$ |
| Treatment * Material * Incubation | $P = 0.12$ | $P = 0.04$ | $P < 0.01$ | $P < 0.01$ |

Mean errors quoted are means of duplicate samples.

[a] is a conventional expression of the % of FFA expressed as Lauric acid.

[b] meq/kg oil.

[c] defined as 100 times the optical density in a solution containing 1 gram of oil in 100 ml

APPENDIX 10

Table 10 The effect of different types of treatments and incubation periods on hydrolytic and oxidative rancidity of PKC kept in plastic bag at room temperature.

| TREATMENTS | | CHEMICAL ASSESSMENT OF RANCIDITY | | | |
|---|---|---|---|---|---|
| Treatments ( ppm ) | Incubation Period (days) | Acidity[a] | Peroxide Value[b] | Anisidine Value[c] | Totox Value[d] |
| | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| Control | 7 | 5.45 ± 0.05 | 3.86 ± 0.01 | 21.77 ± 1.30 | 29.49 ± 1.27 |
| | 14 | 6.97 ± 0.05 | 3.77 ± 0.02 | 29.49 ± 0.51 | 37.02 ± 0.47 |
| | 28 | 6.18 ± 0.02 | 3.49 ± 0.16 | 34.13 ± 0.00 | 41.11 ± 0.31 |
| | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| Santoquin | 7 | 5.53 ± 0.08 | 1.99 ± 0.07 | 9.02 ± 0.25 | 13.00 ± 0.39 |
| ( 175 ) | 14 | 6.58 ± 0.02 | 1.74 ± 0.00 | 6.24 ± 0.42 | 9.72 ± 0.42 |
| | 28 | 6.76 ± 0.07 | 1.15 ± 0.04 | 5.77 ± 0.10 | 8.06 ± 0.17 |
| | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.00 | 13.27 ± 0.00 |
| Aflaban | 7 | 3.32 ± 0.04 | 2.51 ± 0.08 | 17.09 ± 0.14 | 22.10 ± 0.01 |
| ( 200 ) | 14 | 4.18 ± 0.04 | 2.18 ± 0.01 | 11.95 ± 0.10 | 16.31 ± 0.13 |
| | 28 | 4.37 ± 0.06 | 1.58 ± 0.01 | 11.36 ± 0.09 | 14.51 ± 0.11 |
| Santoquin | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.01 | 13.27 ± 0.00 |
| ( 175) + | 7 | 3.45 ± 0.01 | 1.29 ± 0.08 | 11.78 ± 0.87 | 14.36 ± 0.70 |
| Aflaban | 14 | 3.99 ± 0.10 | 1.54 ± 0.08 | 8.13 ± 0.60 | 11.20 ± 0.76 |
| ( 200 ) | 28 | 4.18 ± 0.01 | 1.18 ± 0.00 | 9.82 ± 0.25 | 12.13 ± 0.25 |
| | 0 | 3.19 ± 0.00 | 1.36 ± 0.00 | 10.55 ± 0.01 | 13.27 ± 0.00 |
| Oven dry | 7 | 2.82 - 0.02 | 1.18 ± 0.00 | 2.62 ± 0.02 | 4.98 ± 0.02 |
| ( 60°C ) | 14 | 2.91 ± 0.04 | 1.39 ± 0.01 | 2.89 ± 0.30 | 5.66 ± 0.32 |
| | 28 | 3.36 ± 0.08 | 1.75 ± 0.00 | 0.92 ± 0.01 | 4.42 ± 0.01 |

| Variables : | STATISTICAL SIGNIFICANCE | | | |
|---|---|---|---|---|
| Treatments | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Incubation | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |
| Treatment * Incubation | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ | $P < 0.01$ |

Mean errors quoted are means of duplicate samples.

is a conversional expression of the % of FFA expressed as Lauric acid.

[b] meq/kg oil.

[c] defined as 100 times the optical density in a solution containing 1 gram of oil in 100 ml of a mixture solvent and anisidine.

[d] obtained by addition two times the peroxide value and the corresponding anisidine value.

APPENDIX 11

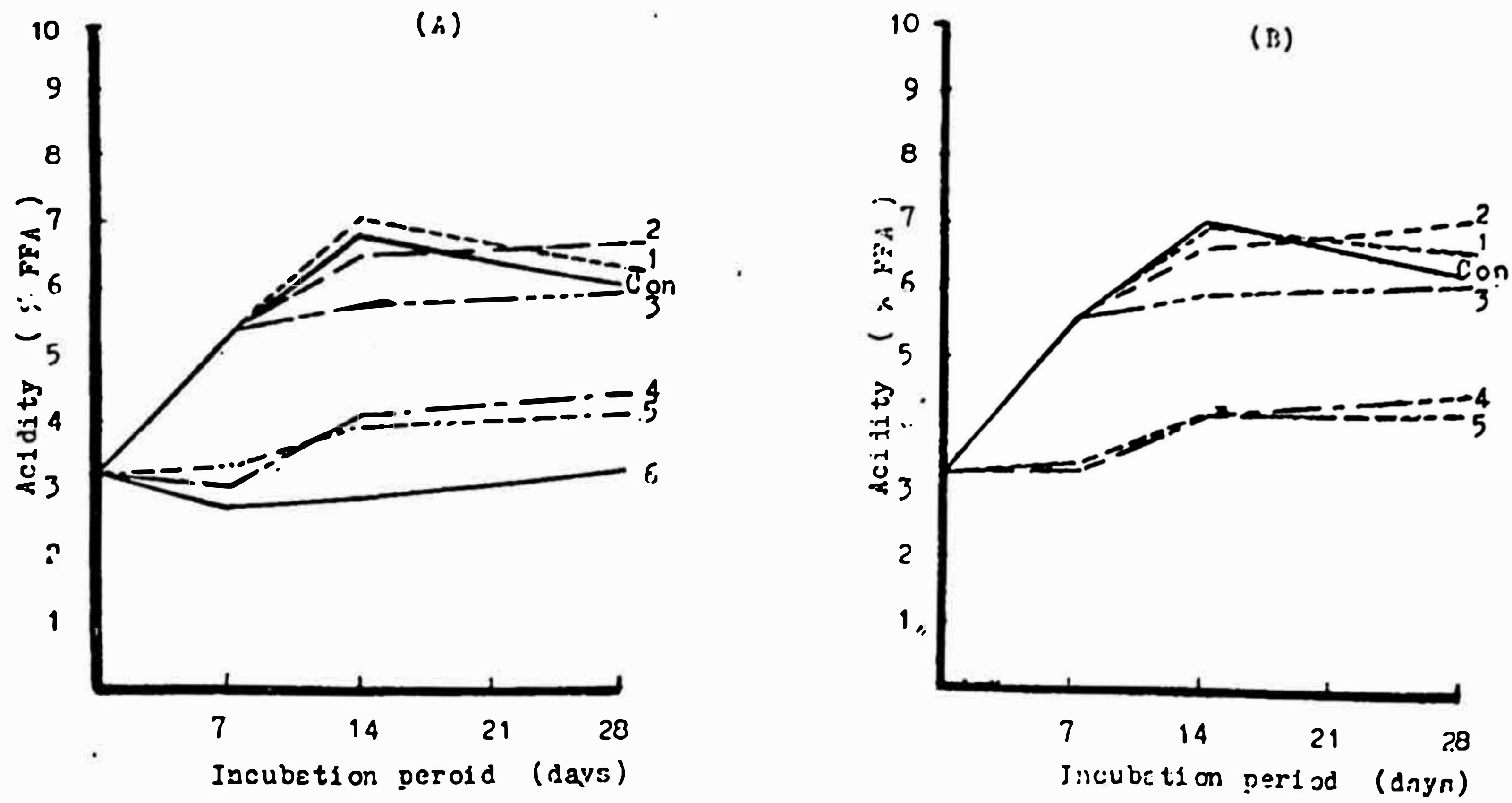



Figure 6: Effect of Santoquin at (1) 100 ppm (2) 175ppm (3) 250 ppm (4) Aflaban at 200 ppm (5) combination of 2+4 and (6) oven dry treatment on the percentage of FFA production of PKC kept in (A) plastic bag and (B) gunny sack at different incubation periods

APPENDIX 12

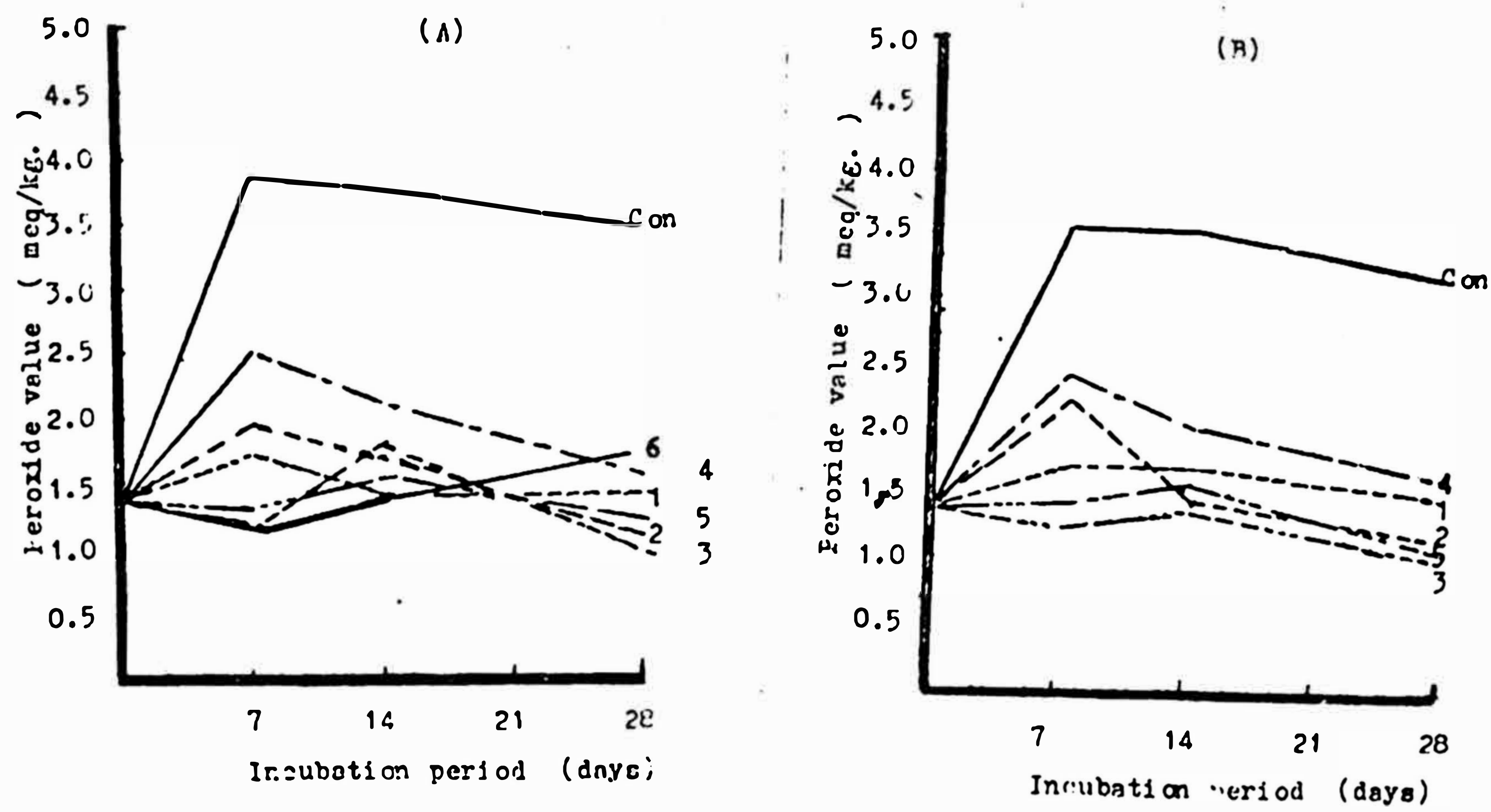



Figure 7: Effect of Santoquin at (1) 100 ppm (2) 175 ppm (3) 250 ppm (4) Aflaban at 200 ppm (5) combination of 2+4 and (6) oven dry treatmet on primary oxidation of PKC kept in (A) plastic bag and (B) gunny sack at different incubation periods.

APPENDIX 13

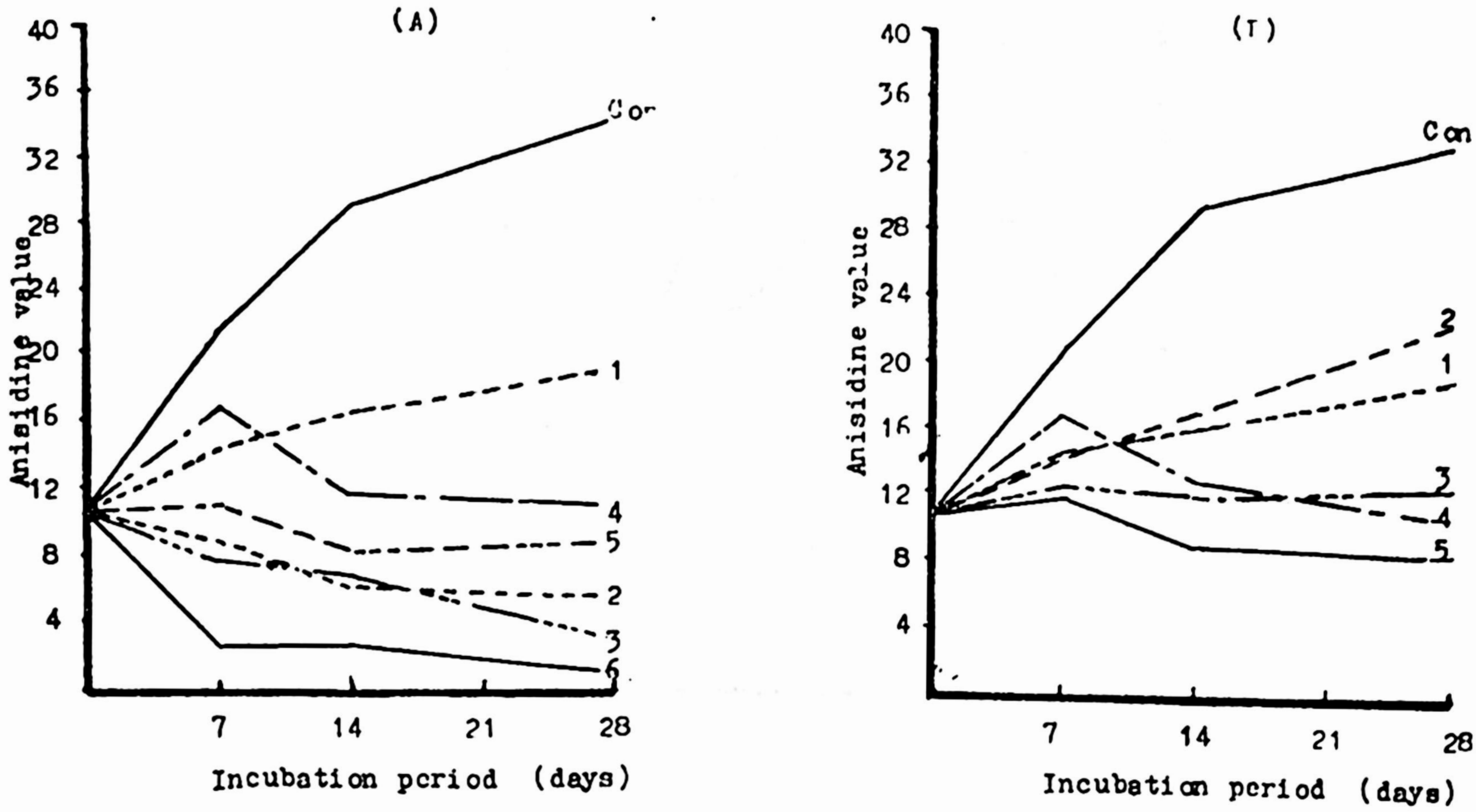



Figure 8: Effect of Santoquin at (1) 100 ppm (2) 175 ppm (3) 250 ppm (4) Aflaban at 200 ppm (5) combination of 2+4 and (6) oven dry treatment on secondary oxidation of PKC kept in (A) plastic bag and (B) gunny sack at different incubation periods.

APPENDIX 14

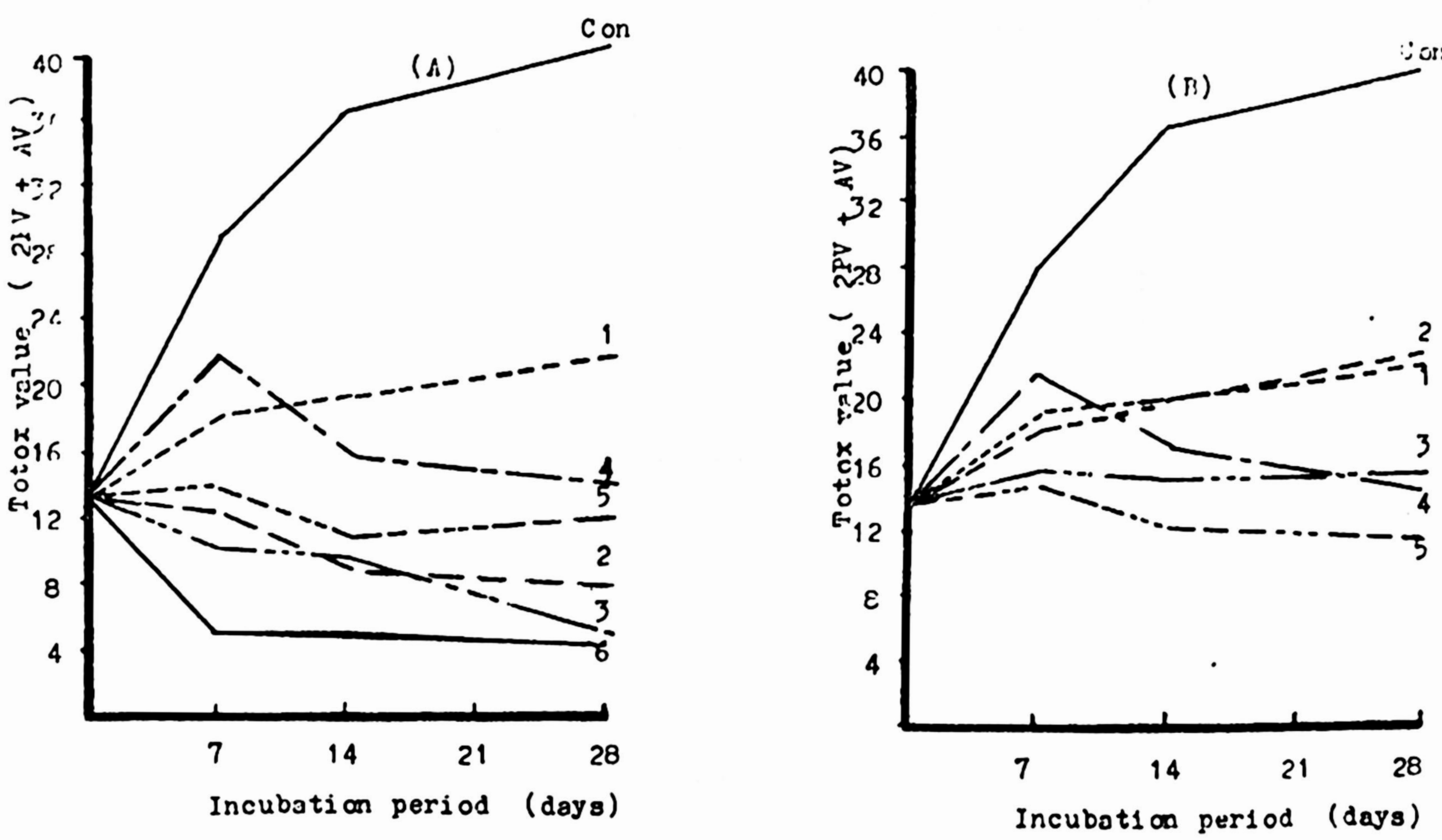
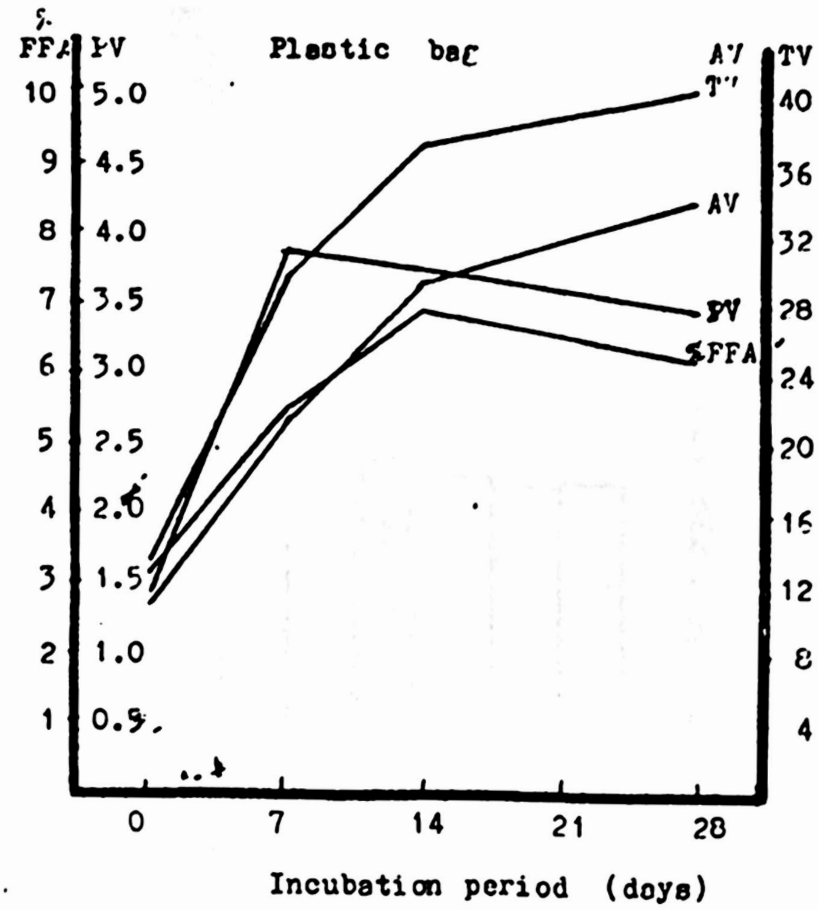



Figure 9: Effect of Santoquin at (1) 100 ppm (2) 175 ppm (3) 250 ppm (4) Aflaban at 200 ppm (5) combination of 4+5 and (6) oven dry treatment on oxidative rancidity of PKC kept in (A) plastic bag and (B) gunny sack at different incubation periods.

APPENDIX 15



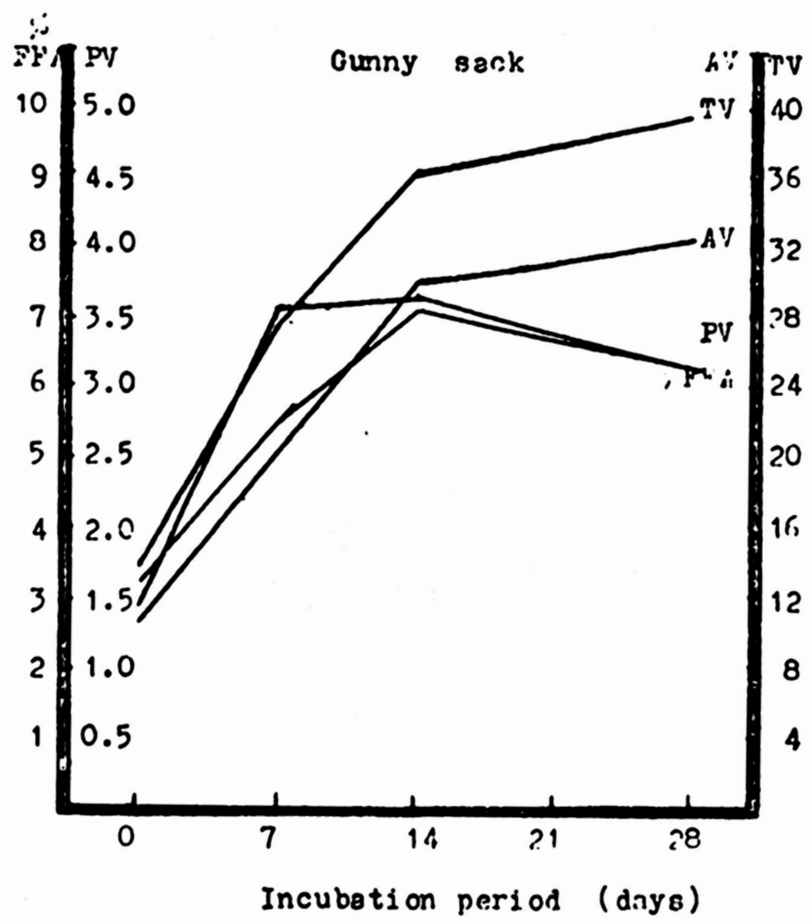




Figure 10: Hydrolytic and oxidative rancidity of untreated PKC during storage (%FFA) Acidity, (PV) Peroxide value (meq/kg), (AV) Anisidine value, (TV) Totox value.

APPENDIX 16

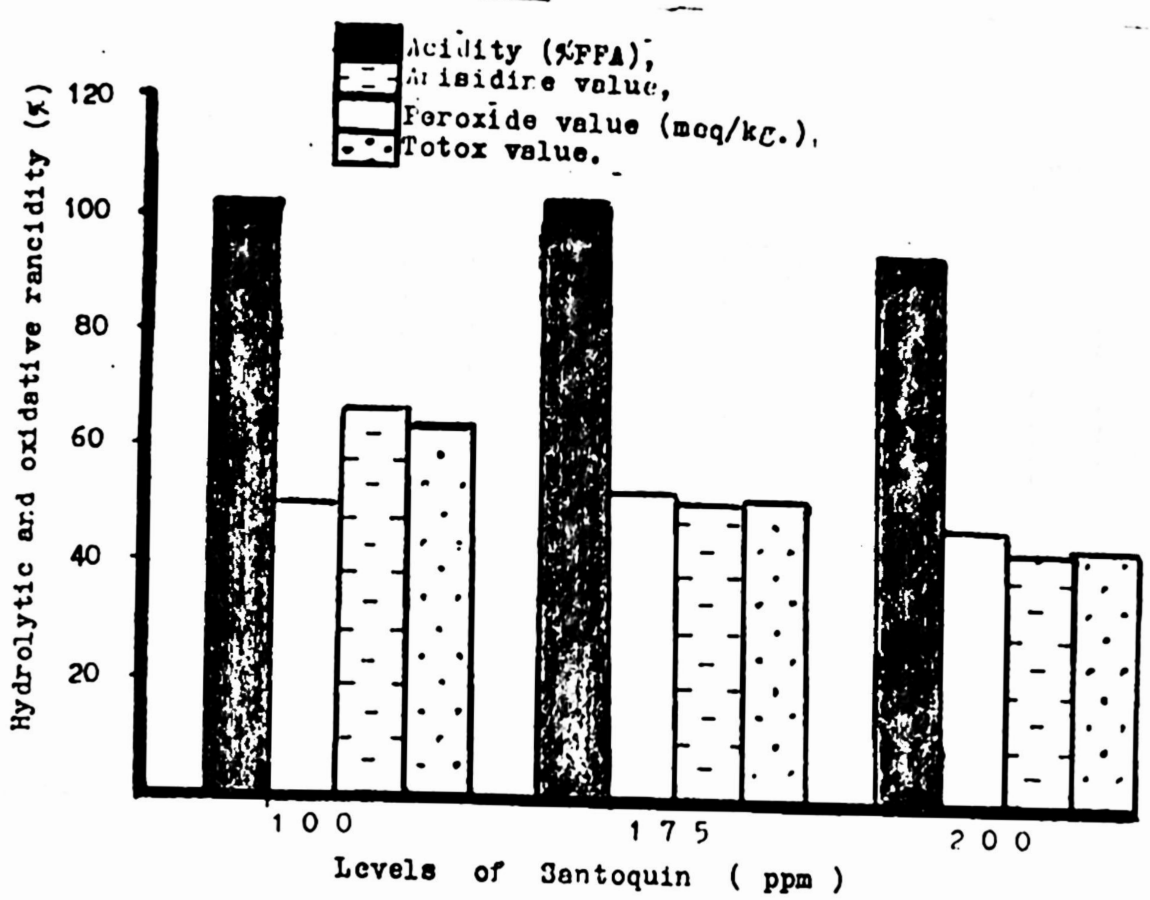



Figure 11: Effect of different levels of Santoquin on rancidity of PKC expressed as percent of Control

APPENDIX 17

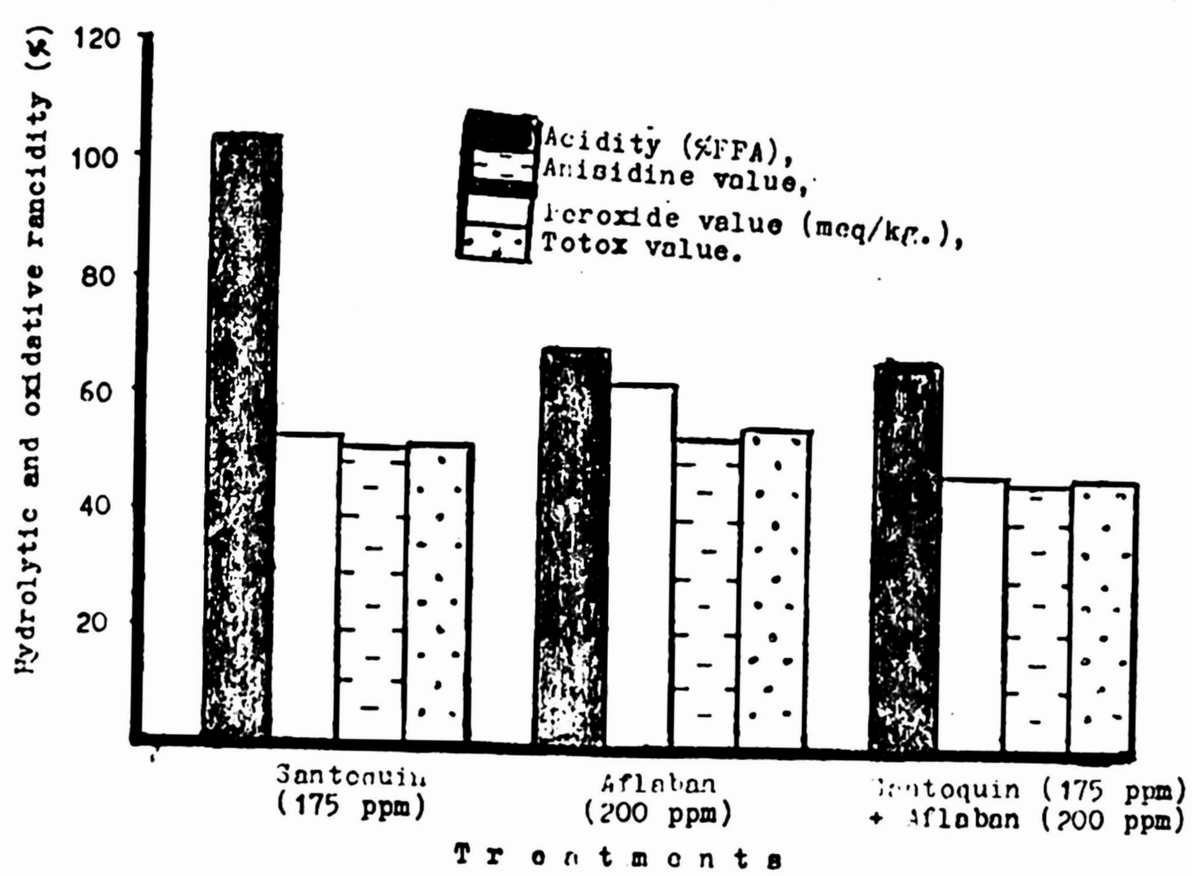



Figure 12: Effect of Santoquin, Aflaban, and their combination on rancidity of PKC expressed as percent of Control.

APPENDIX 18

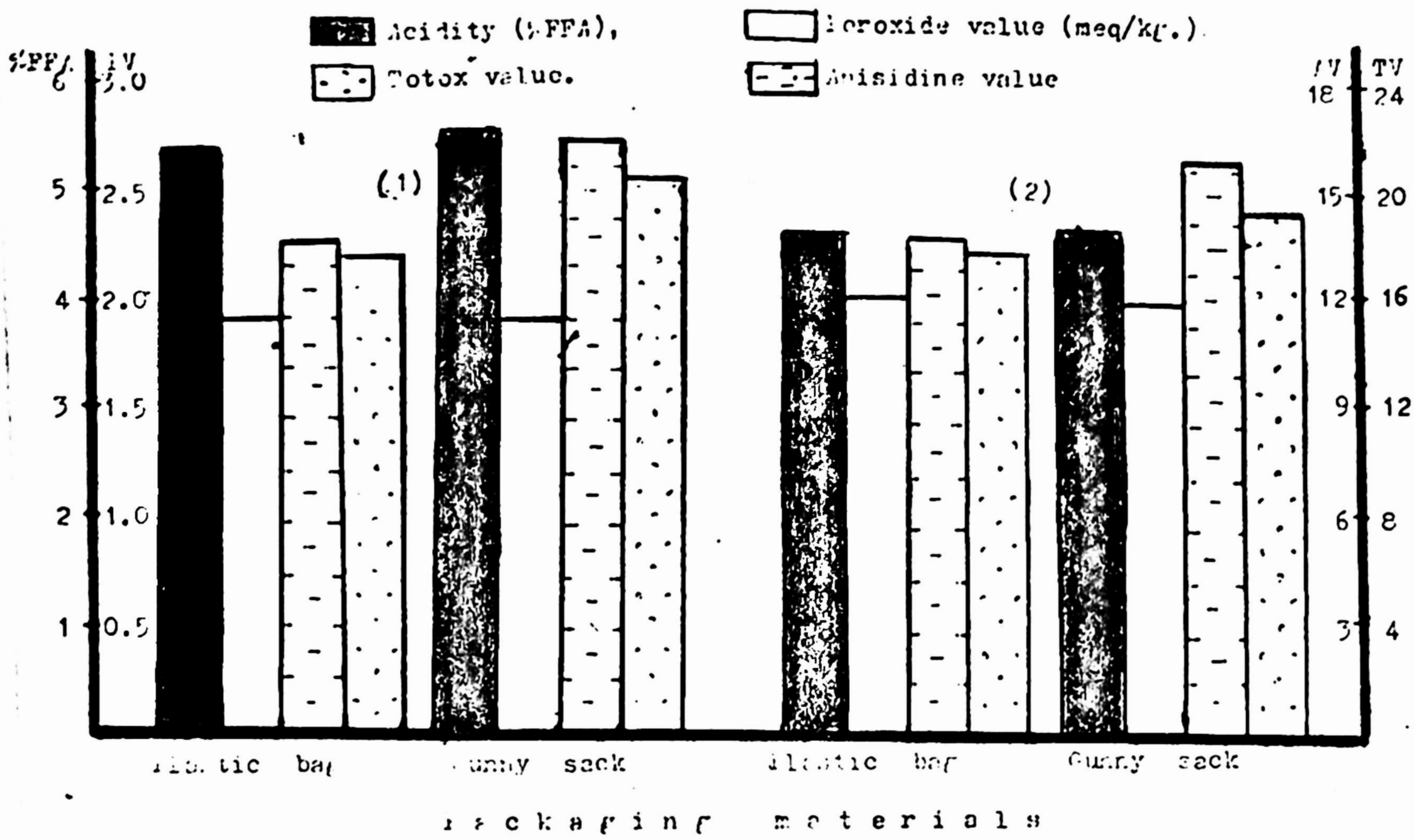



Figure 13: Effect of packaging materials on rancidity of PKC during 28 days of storage.

APPENDIX 19

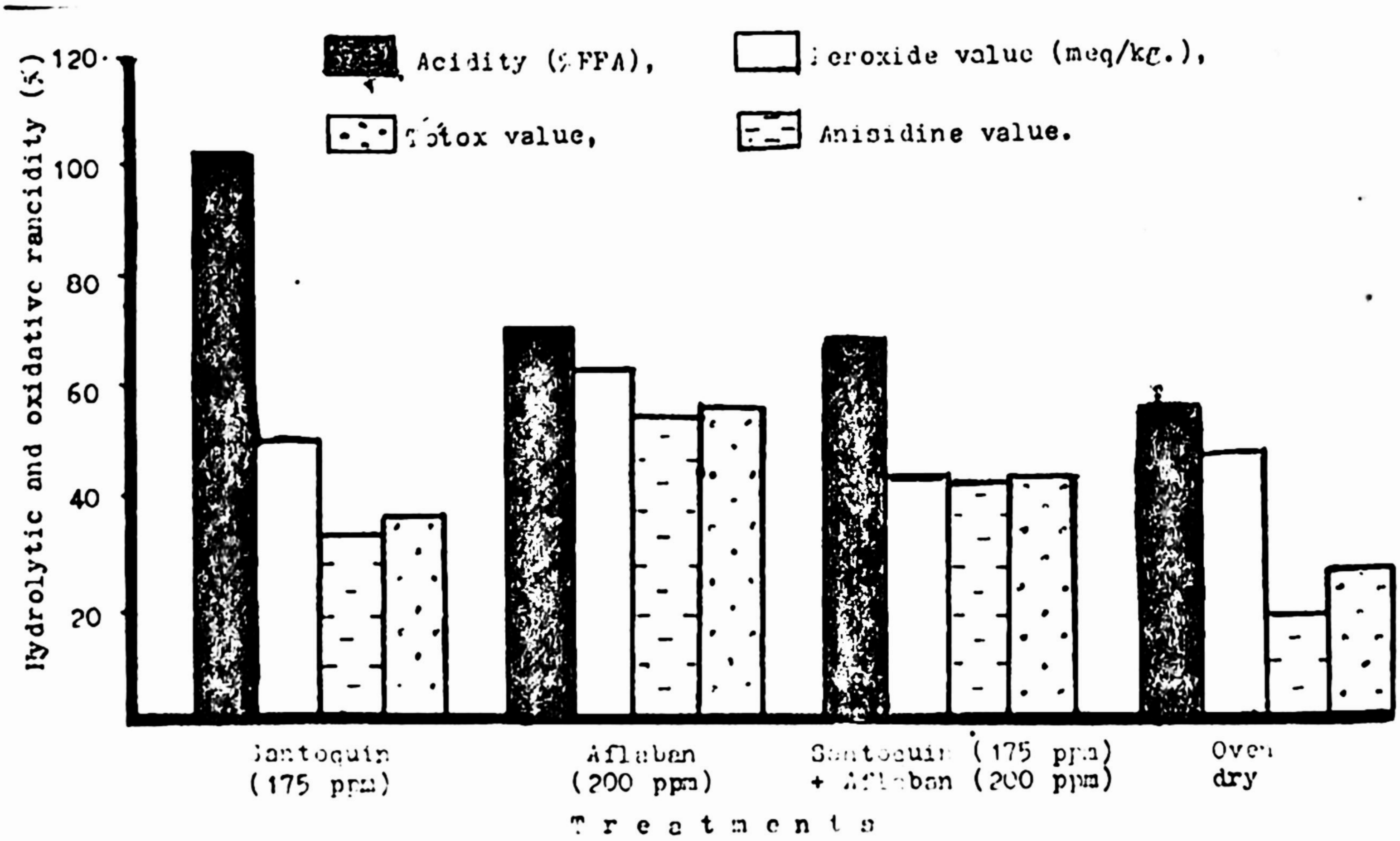



Figure 14: Effect of treatments on rancidity of PKC expressed as percent of Control.