THE EFFECTS OF FATTY ACID BALANCING BY OIL BLENDING ON PERFORMANCE AND UTILIZATION BY GROWING CHICKS

By

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ABSTRACT

The objectives of this research were to investigate the effects of blending Canbra or Canola oil with other oils or fats on the nutritive value and autoxidative stability of the blended oils, and to investigate the possibility of using hydrolyzed oils (free fatty acids) in the study of fatty acid balancing.

Canbra oil (containing 6.1% erucic acid) was blended with sunflower oil or animal lard 1/1 (w/w). Canola oil (0.55% erucic acid) was blended with sunflower oil in the ratios 9/1, 8/2, 7/3, 6/4 and 5/5. The nutritional value was assayed using growing chicks fed lipid at 8% in a practical diet during a 4 week feeding period. Evaluation was made using body weight, weight gain, feed consumption, feed conversion, feed digestibility, lipid digestibility, total fatty acid digestibility, metabolizable energy and individual fatty acid digestibility.

Results show that Canbra oil is equivalent to animal lard but significantly inferior to sunflower oil. Blending Canbra oil and sunflower oil or animal lard improved chick growth and fatty acid utilization over that demonstrated by the Canbra oil alone. Canola oil was equivalent to sunflower oil and soybean oil in supporting chick growth. The 7/3 and 5/5 blends showed synergistic improvement in promoting growth, fatty acid, protein and metabolizable energy utilization. It was concluded that Canola oil is nutritionally equivalent to either sunflower oil or

soybean oil and that blending with sunflower oil further improved its nutritional value. Oil blending rendered no significant detrimental effects on stability.

The fatty acids of hydrolyzed Canola and sunflower oil showed nutritive performance equivalent to that of the intact oils. The fatty acids of a hydrolyzed 5/5 blend of Canola oil and sunflower oil showed reduced absorption of some fatty acids and the fatty acids of hydrolyzed soybean oil showed reduced diet and fatty acid absorption relative to the intact oils. These results demonstrate that feeding hydrolyzed oils may be a useful method of investigating fatty acid balance but more research is required in this area.

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INTRODUCTION

Two families of polyunsaturated fatty acids (linoleic, omega-6; and linolenic, omega-3) have long been recognized as essential for animal and human growth and health. Since most prostaglandins are synthesized from the omega-6 fatty acids (especially arachidonic acid) and the omega-3 fatty acids (especially eicosapentaenoic acid) play an important role in prostaglandin regulation it seems that there must be a quantitatively optimum ratio between these two families of fatty acids which will produce optimum growth and health. In fact, there are clearly identifiable requirements for these individual fatty acids but once these requirements have been met a balance between these fatty acids is a critical factor to enable conditions to be achieved for cellular equilibrium of prostanoids and membrane stability (Crawford et al, 1982). The quantitative requirement of essential fatty acids, therefore, must be met with an adequately balanced ratio of fatty acids (Holman, 1982).

Rapeseed oil, soybean oil and sunflower oil are the major oil products in Canada. Rapeseed and soybean oils are recognized as being amoung the few edible vegetable oil sources which are rich in both families of essential fatty acids. However, it has been well documented that feeding rapeseed oil results in decreased feed intake and growth in several species (compared to

soybean oil). In the past this has been attributed to the high content of erucic acid in rapeseed oils. Recently, rapid developements in plant genetics and the introduction of new cultivars for production have reduced the erucic acid content of the Canadian rapeseed oils. These new cultivars have been designated low erucic acid rapeseed (LEAR). The first change from rapeseed oil to LEAR oil reduced the erucic acid content from 20-40% to less than 5.0%. These oils were commercially designated as Canbra oils. Even more recently there has been another movement toward the production (for consumption) of cultivars that are even lower in erucic acid content (generally less than 2%) and also low in glucosinolates. These cultivars have been commercially designated as Canola.

In spite of this the Canbra and Canola oils, although improved, still tend to show low performance in promoting animal growth relative to soybean oil. This low performance has been overcome by blending rapeseed oil with either animal lard or tallow. This blending synergistically improves not only the consumption of feed but weight gain and fat utilization in experimental animals. This has led to the suggestion that rapeseed oil has a fatty acid profile that is inadequate for maximal fat utilization. It has also been suggested that the synergism between fats is highly interactive and its explanation lies in an understanding of digestion and absorption (Freeman, 1983).

These facts combined with reports that in Algeria Canola oil is blended exclusively with sunflower oil to produce a consumer

product (SAFIA) (Cambell, 1982) led to the research reported herein. The objectives of this research were to compare the nutritive qualities of dietary sunflower oil, soybean oil, Canbra oil, Canola oil, animal lard, blends of Canbra oil and sunflower oil or animal lard and blends of Canola oil and sunflower oil. The effects of blending on the autoxidative stability of the blends was also investigated.

LITERATURE REVIEW

Fat Supplementation in Poultry Rations

It has long been thought that due to their high energy density fats and oils (of both animal and vegetable origin) would be useful feed ingredients. This has resulted in numerous publications on the utilization of fat and oil by poultry over the years. It is generally conceded that indeed poultry can tolerate high levels of fat in the diet if certain conditions are met.

However this was not always so. Henderson and Irwin (1940) reported that soybean oil was detrimental to chick growth when added at levels over 10% of the diet. In addition Yacowitz (1953) reported that supplementation of 2.5 or 5.0% of cottonseed oil, soybean oil or lard produced increased growth in broilers but more than 10% of these fats in the diet retarded chick growth.

More recent literature sheds some light on these results. Biely and March (1954, 1957) showed that dietary supplementation with fat increased the efficiency of protein utilization. The addition of fat to diets with adequate protein improved both growth and feed efficiency, but if the protein level is low fat supplementation will retard both parameters. This pointed to the fact that the energy to protein ratio of a diet is important to the chick. These results were confirmed by

Donaldson et al (1957), Scott et al, (1955) and Waibel (1955,1958) for both chicken and turkeys.

It was discovered that poultry could tolerate high levels of fat providing the dietary level of protein was also increased. Donaldson et al (1957) reported that up to 33.8% fat can be used in a chick diet providing an adequate energy/protein ratio was maintained. This was confirmed by Rand et al (1958) who reported that the chick's tolerance for fat, per se, is essentially unlimited.

Several experiments that have been undertaken to demonstrate the effect of addition of fats to the diets on the performance of poultry have led to the general conclusion that dietary fat improves both feed efficiency and growth (Biely and March, 1954; Donaldson et al, 1957; Rand et al, 1958; Dam et al, 1959; Menge and Denton, 1961; Vermeersch and Vanschoubroek, 1968; Bragg et al, 1973; and Horani and Sell, 1977). This improvement is not directly related to the level of fat added to the diet and appears to differ depending on the source of the fats and oils (Carew et al, 1964; Vermeersch and Vanschoubroek, 1968; Bragg et al, 1973).

The increased dietary efficiency has often been attributed to the "extracaloric effect" of fat. This effect was clearly demonstrated in chickens (Rand et al, 1958; Menge and Denton, 1961; and Carew et al, 1964). More recently Horani and Sell (1977) used the term "extra metabolic effect" to describe the change in ration metabolizable energy (M.E.) caused by the addition of fat. Leeson and Summers (1976) proposed a hypothesis

which stipulated the existance of an interaction between the fatty acids inherent in ration ingredients with the added fat which results in increased M.E. content of the fat.

Fat Digestion and Absorption in Poultry

There is little difference in the digestion and absorption of fats between the avian and the mammalian species except for the mucosal products of absorption and their route of transport. Therefore, the following brief description is a compilation of information gleaned from Guyton (1976), Griminger (1976) and Scott et al (1982) except where specifically noted.

By far the most common lipid constituent of a diet is the triglyceride portion which makes up the majority of fats and oils. The first step in digestion of triglycerides is the emulsification of the fat by bile salts to provide a larger surface area for the water-soluble digestive enzymes to act upon.

The conjugated bile salts possess dissymetric polar and non-polar regions, the polar region is highly soluble in water and the non-polar region is highly soluble in fat. Therefore, bile salts aggregate on the surface of fat globules in the intestine with the carboxyl portion of the bile salt projecting outward and soluble in the surrounding fluids and the sterol portion dissolved in the fat. This effectively decreases the interfacial tension of the fat allowing fragmentation by agitation and therefore the bile salt acts as a detergent. This fragmentation results in smaller emulsion globules.

With increasing surface area due to emulsion the activity of

the pancreatic juice is greatly accelerated. The pancreatic juice contains several lipolytic enzymes and bicarbonate. These enzymes include pancreatic lipase, carboxylic ester hydrolase and co-lipase (Borgstrom, 1977). The pancreatic lipase hydrolyzes the dietary triglycerides to an equilibrium mixture of tri-, di- and monoglycerides and fatty acids. This lipase is specific for the ester bonds in the primary positions of the glycerides and has a specificity in relation to fatty acid chain length and degree of saturation (Morely et al, 1974). The carboxylic ester hydroxylase hydrolyzes sterol esters, vitamin A esters and long chain monoglycerides and appears to require bile salts to be active (Borgstrom, 1977). Co-lipase is a polypeptide co-factor which functions to take the lipase back to the substrate interface in the presence of bile salts. The bicarbonate of the pancreatic juice is also important as it aids in the rapid emulsification of fats by the formation of soaps as recognized by Rockford in 1891 (Borgstrom, 1977).

The hydrolysis of triglycerides is a highly reversible process, therefore the accumulation of monoglycerides and free fatty acids quickly blocks further digestion. However, bile salts play an important role in the removal of monoglycerides and fatty acids from the area of fat digestion through their propensity to form micelles. These micelles are small globules about 25 Angstroms in diameter, composed of 20-50 molecules of bile salt. Because of their dissymetrical polar-nonpolar structure the sterol nuclei of the 20-50 bile salt molecules aggregate to form a small fat globule. This aggregation allows

the polar molecules to extend outward and cover the exterior of the micelle. Since these are negatively charged they allow the entire micelle to dissolve in the polar solution in the alimentary tract.

The lipid-bile salt (mixed) micelle is able to dissolve relatively large amounts of non-polar compounds within its interior. In this form non-polar, high melting point fatty acids, monoglycerides and other lipid materials are solubilized in the aqueous phase of the intestinal contents and transported to the mucosal cell membrane (away from the site of fat digestion) where they are absorbed.

Fatty Acid Absorption

When the micelles come in contact with the epithelial mucosa both the monoglycerides and free fatty acids diffuse through the epithelial membrane. This is due to the fact that they are both highly lipid soluble and actually dissolve in the cell membrane. The undigested triglycerides and diglycerides are also soluble in the cell membrane but are not highly absorbed, as they do not dissolve in the micelles and are not transported to the epithelial membrane.

The percentage absorbability of fats or fatty acids is affected by several factors:

(1) The chain length of the fatty acids (Carroll, 1958; Hamilton and McDonald, 1969; Renner and Hill, 1961b; Ward and Marquardt, 1983);

(2) the degree of unsaturation (Carroll and Richards, 1958;

Renner and Hill, 1961b; Hamilton and McDonald, 1969; Whitehead and Fisher,1975; Austreng et al, 1979; Kussaibati et al, 1982; Atteh and Leeson, 1983; Ward and Marquardt, 1983);

(3) the presence or absence of ester linkages (Carroll and Richards, 1958; Renner and Hill, 1961a; Sklan, 1979) although this has been questioned (Young, 1961; Young and Garrett, 1963; Young et al, 1963);

(4) the specific arrangement of the fatty acids on the glycerol moiety of the triglyceride (Fedde et al, 1960; Renner and Hill, 1961a; Hamilton and McDonald, 1969; Whitehead and Fisher, 1975);

(5) the age of the experimental animal (Fedde et al, 1960; Renner and Hill, 1960; Renner and Hill, 1961b; Young et al, 1963; Hakansson, 1974; Whitehead and Fisher, 1975; Salmon, 1977; Muztar et al, 1981; Ward and Marquardt, 1983) although this may not be true in the weanling pig (Hamilton and McDonald, 1969);

(6) the relative ratios of fatty acids in the oil or free fatty acid mixture (Hopkins et al, 1955; Renner and Hill, 1961a; Young and Garrett, 1963; Rocquelin and Leclerc, 1969; Salmon, 1970; Walker et al, 1970; Kramer et al, 1973; Lall and Slinger, 1973; Salmon, 1977; Chow and Hollander, 1979; Corino et al, 1980; Mateos and Sell, 1981; Muztar et al, 1981; Fuller and Dale, 1982; Freeman, 1983; Hulan et al, 1984);

(7) the composition of the diets in which the fats are fed (Carroll and Richards, 1958; Fedde et al, 1960; Renner and Hill, 1961b; Young et al, 1963; Hakansson, 1974; Mateos

and Sell, 1981; Muztar et al, 1981; Fuller and Dale, 1982; Ward and Marquardt, 1983);

(8) the amount of bile salts in the alimentary tract.

In addition, it has been shown that the chicken intestine contains a fatty acid binding protein (Katongole and March, 1979) that increases with age and fat in the diet (Katongole and March, 1980) and is similar to that described in rats (Ockner et al, 1972), but the significance of this binding protein in fatty acid absorption has not yet been demonstrated.

Essential Fatty Acids

In 1929 Burr and Burr showed that exclusion of fat from rat diets caused a deficiency syndrome in which the rats grew normally for 4-6 months and then suffered growth failure and death. This growth failure was accompanied by dermatitis. In 1930 these researchers further demonstrated that the polyunsaturated fatty acids linoleic, linolenic and arachidonic possessed a biopotency that prevented the dermatitis, growth failure and death which was not prevented by antixerophthalmic or antirachitic factors or individual saturated fatty acids. These three fatty acids have since become known as the essential fatty acids (EFA).

A dietary requirement for the EFA has been demonstrated in chicks (Reiser, 1950; Bieri et al, 1956; Machlin and Gordon, 1960). EFA deficiency in the diet resulted in reduced growth rates, enlarged livers with increased fat content and reduced resistance to respiratory infections (Hopkins et al, 1963;

Balnave, 1970). It is now well established that these symptoms are due to the fact that the EFA have important physiological roles in maintaining the structural integrity of cellular membranes as well as serving as precursors of the autocoids (prostaglandins, thromboxanes, leukotrienes, prostacyclins and hydroperoxy fatty acids). These autocoids are important in thrombocyte and platelet function, cardiac function and smooth muscle contraction (Holman, 1975; Vergroesen et al, 1975; Murphy et al, 1979; Sprecher, 1983).

Nutritional and Metabolic Relationships Between Fatty Acid Families

Lipid metabolism as well as fat absorption is affected by the fatty acid composition of a diet. Nunn and Smedley-MacLean (1938) showed that 5,8,11-eicosatrienoic acid was dramatically increased in the liver tissue of EFA deficient rats. Fulco and Mead (1959) showed that 5,8,11-eicosatrienoic acid was a metabolite of oleic acid. This was the first evidence of dietary and metabolic interrelationships between specific fatty acids. Mead (1961) suggested that there were four separate families of fatty acids that were the metabolites of palmitoleic acid (C16:1w7), oleic acid (C18:1w9), linoleic acid (C18:2w6) and linolenic acid (C18:3w3) and which were not interconvertable. This confirmed the radio-isotope work of Steinberg et al (1957), Klenk and Mohrhauer (1960). The literature pertaining to this was reviewed by Sprecher (1981). The chief metabolite of the linoleic acid pathway is arachidonic acid (5,8,11,14-20:4w6)

(Widmer and Holman, 1950; Steinberg et al, 1956; Sprecher, 1975). The chief metabolite of the oleic acid pathway is eicosatrienoic acid (5,8,11-20:3w9) (Fulco and Mead, 1959; Sprecher, 1975; Sprecher, 1981). The ratio of these 2 fatty acids (triene/tetraene) was suggested as an indicator of EFA deficiency in humans (Holman, 1960). The basis of this is the fact that linoleic and oleic acid compete for the same 6-desaturase (Holman, 1964). When there are sufficient amounts of linoleic acid in the diet the conversion of oleic acid to eicosatrienoic acid is competitively inhibited keeping the triene/tetraene ratio low.

The chief products of linolenic acid metabolism are eicosapentaenoic acid (5,8,11,14,17-20:5w3) and docosahexaenoic acid (4,7,10,13,16,19-22:6w3) (Widmer and Holman, 1950; Steinberg et al, 1957; Klenk and Mohrhauer, 1960; Sprecher, 1975 and 1981). Docosahexaenoic acid is the member most often found in land animals while eicosapentaenoic acid is common in marine mammals and fish (Tinoco et al, 1979). The presence of members of the linolenic acid pathway has 2 consequences. They are antagonistic to the conversion of linoleic acid to arachidonic acid (Machlin, 1962; Mohrhauer and Holman, 1963), and they compete for cycloxygenase and lipoxygenase with arachidonic acid (Lands, 1975; Beare-Rogers et al, 1979; Needleman et al, 1979). This competition gives rise to autocoids which have antagonistic physiological functions that can possibly be manipulated by alteration of dietary fatty acid composition, which might be useful in decreasing thrombic tendencies and

myocardial infarcts (Needleman et al, 1979).

The palmitoleic acid metabolites are relatively unimportant due to their low rates of desaturation and failure to form autocoids (Sprecher, 1975, 1981).

Relative Nutritional Properties of Rapeseed Oil

It is well known that oils and fats have characteristic fatty acid profiles. Given the factors affecting lipid digestion, fatty acid absorption and fatty acid metabolism it is not surprising that the literature contains many reports of varying nutritional values for oils and fats of similar gross energies. Indeed this was clearly shown in the review article of Vermeersch and Vanschoubroek (1968). In Canada this has led to extensive research involving rapeseed oil (Canada's largest oil seed crop). Much of this work was stimulated by Deuel et al who in 1948 demonstrated that not only butterfat but corn, cottonseed, olive, peanut and soybean oils outperformed rapeseed oil in rat growth trials and implicated erucic acid in the poor performance of this oil (Sauer and Kramer, 1983). In subsequent years these results were amply confirmed in rats (Alexander and Mattson, 1966; Craig and Beare, 1968; Rocquelin and Cluzan, 1968; Walker et al, 1970; Kramer et al, 1973; Ziemlanski, 1977), chickens (Sell and Hodgson, 1962; Salmon, 1969b; Sheppard et al, 1971; Clandinin et al, 1978; Hulan et al, 1982) and in turkeys (Joshi and Sell, 1964; Salmon, 1969a).

In addition it was reported that rapeseed oil depressed rat feed efficiency relative to peanut, corn or olive oil (Rocquelin

and Cluzan, 1968; Walker et al, 1970) and energy utilization relative to corn and olive oil (Walker et al, 1970). However, in 1966 Alexander and Mattson reported that rapeseed oil was energetically equivalent to soybean oil and that some of the "toxicity" reported earlier was due to the methods of dietary presentation. However, this is doubtful in the cases of the studies of Rocquelin and Cluzan (1968) and Walker et al (1970).

In chickens it was reported that feed efficiency was depressed by rapeseed oil relative to soybean oil (Salmon, 1969b; Hulan et al, 1982) and corn and olive oil (Walker et al, 1970). As in rats it was also shown that rapeseed oil reduced energetic efficiency relative to corn and olive oil (Walker et al, 1970) and sunflower oil (Clandinin et al, 1978) but was equivalent in this respect to soybean oil (Salmon, 1969b) as was suggested by Alexander and Mattson (1966).

The data for turkey poults is even more confusing. Joshi and Sell (1964) reported no significant differences between the feed efficiency of diets containing soybean oil, sunflower oil, animal tallow or rapeseed oil but that at 5% inclusion in the diet the M.E. of the total diet was significantly higher for sunflower oil than that of the rapeseed oil, soybean oil or animal tallow diets which were equivalent, and that at 10% inclusion in the diet the M.E. of the total diet was significantly higher for the rapeseed oil diet than was the M.E. for the sunflower oil, soybean oil or animal tallow diets which were equivalent. However, Salmon (1969a) reported that rapeseed

oil depressed both feed and energetic efficiency at 11 and 14 days of age but not after that in turkey poults.

The most consistent feature of all these reports is the reduced weight gain produced by feeding rapeseed oil. This has been blamed on several factors, which include: decreased feed consumption solely (Joshi and Sell, 1964; Alexander and Mattson, 1966), decreased consumption and decreased energy utilization due to dietary oil induced changes in membrane phospholipids which indicated a complex dynamic mechanism associating mitochondrial structural-functional transitions due to dietary fatty acid balance (Clandinin et al, 1978); decreased feed efficiency due to increasing levels of poorly absorbed erucic acid (Hulan et al, 1982); and an unbalanced fatty acid profile in rapeseed oil which does not allow maximum fat utilization or absorption (Rocquelin and Cluzan, 1968; Walker et al, 1970; Kramer et al, 1973). The fatty acid profile hypothesis was also supported by Salmon (1969a) who reported that growth depression of poults was not a result of consumption, and could not be attributed solely to erucic acid but seemed to correspond roughly with the dietary content of saturated fatty acids.

In addition to problems associated with growth and energy utilization, it was reported in 1960 that myocardial damage occured in young male Sprague-Dawley rats fed rapeseed oil over long periods, however these researchers did not refer to early literature and left the impression that this was a unique property of rapeseed oil rather than a general effect of high fat diets in the rodent (Sauer and Kramer, 1983). Abdellatif and

Vles (1970) reported that feeding rapeseed oil (49% erucic acid) at 50% of the dietary calories caused rapid and severe fat infiltration of the rat myocardium. These findings were quickly confirmed (Houtsmuller et al, 1970; Beare-Rogers et al, 1971; Kramer et al, 1973).

Developement of Low Erucic Acid Rapeseed oil

The Canadian Food and Drug Directorate had (since 1958) no objections to the use of rapeseed oil in moderate amounts in Canadian food (Daun, 1983). However, even though no evidence had been presented indicating human health problems existed the Minister of National Health and Welfare, on August 12, 1970, stated that the Federal Government felt that it was "prudent to accelerate Canada's change over to erucic acid free rapeseed" and as a result, by 1973, the majority of Canadian crushing plants were able to produce rapeseed oil with levels of erucic acid lower than 5% without blending with other oils (Daun, 1983). This resulted in a dichotomy of rapeseed oil types. The varieties in production prior to 1970 with erucic acid levels ranging from 20-40% became known as high erucic acid rapeseed oils (HEAR) and the new varieties (which had been developed in Winnipeg and Saskatoon as early as 1960 and 1963) became known as low erucic acid rapeseed oils (LEAR) which had by definition less than 5% erucic acid, and were given the trade name Canbra. In 1975 another change was initiated. This was the change over to newer LEAR varieties which had been developed and contained less than 5% erucic acid (often less than 2%) and low levels of

glucosinolates (Daun, 1983). These varieties were given the trade mark Canola. The major difference between the Canbra and Canola oils was the sulfur level which reflected the decrease in the glucosinolates in the Canola (Daun, 1983).

These changes in the Canadian industry promoted continued research in the areas of rapeseed oil cardiotoxicity as well as the nutritional quality of rapeseed oil. However, there was also much interest not only in the comparison of rapeseed oil with oils of other origins but with the comparisons of HEAR with LEAR.

Nutritional Properties of Low Erucic Acid Rapeseed Oil

Hulan et al (1977) reported no pathological abnormalities in laying hens or hooded rats fed either HEAR or LEAR. This was confirmed by Vles et al (1977) who could show no cardiotoxic effects of LEAR in monkeys, pigs or poultry although there did appear to be cardiotoxic effects in fast growing strains of rats. This was in agreement with Kramer et al (1977) who reported that myocardial lipidosis is mild or undetectable when LEAR is fed to male chicks, rats, pigs and monkeys. However, the unbalanced fatty acid profile resulted in myocardial necrosis in the male rats but not in the other experimental animals. These results were confirmed by Kramer et al (1979) when they observed that LEAR intake does not increase heart lesion incidence in Chester-Beatty rats, mice, pigs, monkeys, ducks or chickens relative to soybean oil intake even though the omega-3 fatty acids combined with low levels of saturated fatty acids was cardiotoxic to male Sprague-Dawley

rats. It is now generally accepted that LEAR is not cardiotoxic (except to rats). Other species develope heart lesions that are not generally fat related and seem to have a different etiology (Kramer and Sauer, 1983).

Craig and Beare (1968) reported that Canbra oil was nutritionally superior to HEAR. This was confirmed for rat weight gain by Rocquelin and Cluzan (1968), Walker et al (1970), and Kramer et al (1977). Vles et al (1977) reported that the reduction of erucic acid content of rapeseed oils had considerably improved its nutritional properties.

Walker et al (1970) reported that LEAR produced superior growth in chicks and poults than did HEAR. This was supported by Lall and Slinger (1973), Kramer et al (1977) (for male chicks) and Clandinin et al (1978) (chicks). It was also reported that LEAR gave improved feed efficiency over HEAR in rats (Rocquelin and Cluzan, 1968) and chicks and poults (Lall and Slinger, 1973); Hulan et al, 1982). The reports of energy efficiency of LEAR relative to HEAR are conflicting. Walker et al (1970) reported that LEAR was a superior source of energy for chicks, poults and rats but Clandinin et al (1978) reported that HEAR was superior to LEAR for energy utilization.

When LEAR was compared with other oils in terms of weight gain or productivity in rats it was reported that LEAR was not significantly different from poppyseed oil (Beare-Rogers et al, 1979), sunflower seed oil (Beare-Rogers et al, 1979; Ziemlanski, 1977), peanut oil (Rocquelin and Cluzan, 1968; Engfeldt and Brunius, 1975), olive oil or corn oil (Walker et

al, 1970), or soybean oil (Ziemlanski, 1977). However, Kramer et al (1973) reported that corn oil> soybean oil> LEAR (1.6% erucic acid)> LEAR (4.3% erucic acid) in rat growth promotion when fed at 20% of the diet. This was supported by Kramer et al (1981) and Farnworth and Kramer (1983) who reported that soybean oil promoted significantly more growth than LEAR (0.6% erucic acid). This they attribute to the relative fatty acid patterns of the LEAR and soybean oil.

The data for poultry is just as conflicting. Walker et al (1970) reported no significant differences in growth for chicks or poults fed diets containing LEAR, corn oil or olive oil, and March (1977) reported no significant differences in productivity of New Hampshire chicks or White Leghorn cockerels fed 4% rapeseed oil or corn oil or 10% rapeseed oil or soybean oil. However, Clandinin et al (1978) reported that LEAR was significantly inferior to sunflower oil in promoting chick growth and Hulan et al (1982) reported that LEAR was inferior to soybean oil in the growth promotion of chicks at 8 and 12 weeks but not at 4 and 16 weeks.

In terms of feed efficiency, Hulan et al (1982) reported that LEAR was significantly inferior to soybean oil for chicks, while Walker et al (1970) reported that LEAR was equivalent to corn oil and olive oil for chicks, poults and rats in terms of feed and energy utilization. Clandinin et al (1978) reported that energy utilization was higher in chicks fed sunflower oil than those fed LEAR.

It is clear that the genetic selection which reduced the

erucic acid content of rapeseed oil also improved its nutritional value. However, it has not been conclusively demonstrated whether or not LEAR is nutritionally equivalent to sunflower oil and soybean oil although it would seem there is probably little difference in ability to promote weight gain.

Synergistic Effects of Blending Oils

In 1960, Sibbald and Slinger reported "a synergistic relationship between tallow and undegummed soybean oil". These researchers found that a 50/50 mixture of tallow and undegummed soybean oil had a metabolizable energy of 8.41 cal/gm which was not significantly different from that of the soybean oil alone (8.46 cal/gm) but was significantly higher than the value of 6.94 cal/gm obtained for the tallow alone. This indicated that the M.E. values of fats are not additive. The combined M.E. value was higher than would be expected from the two M.E. values of the fats fed individually. These results were confirmed by Sibbald *et al* (1961) who attributed the synergism to a factor or factors in the undegummed soybean oil which allowed an increased utilization of the palmitic and stearic acids in the tallow. Further work (Sibbald *et al*, 1962) indicated that this synergism was at least partially independent of the M.E. effects and that the synergism between fats also expressed itself in chick weight gains and feed efficiency. The weight gains of the chicks fed fat mixtures were greater than expected even when adjusted for equal feed intake, calorie/protein ratio and constant M.E. concentration. This was further supported by

Artman (1964) who also reported synergistic effects of blending tallow and soybean oil on chick energy utilization and growth. Since Young and Garrett (1963) had shown that unsaturated fatty acids could influence the utilization of saturated fatty acids it was suggested that the absorbability of a fat mixture was influenced by its fatty acid content. Artman felt that his results strongly supported this as he showed that the same synergistic effects occured whether the relatively saturated and unsaturated fatty acids were supplied both as neutral triglycerides, both as free fatty acids or as mixtures of triglycerides and fatty acids. It was also shown that the addition of soybean oil to tallow yields not only the expected high utilization of soybean oil but to equally good utilization of a portion of the tallow equal in weight to the weight of the soybean oil added. This increased utilization was shown clearly by Lewis and Payne (1966) who reported that adding 5% soybean oil (as a proportion of total added dietary fat) to beef tallow increased the total apparent fat absorption from 66% (for pure beef tallow) to 80%, adding 10% soybean oil increased total apparent fat absorption to 85% and 20% soybean oil increased absorption to 86.0%.

It was soon shown that rapeseed oil also showed synergistic interactions when blended with animal tallow in the diets of both chickens and rats. In fact, synergism was shown in energy utilization (Walker et al, 1970; Lall and Slinger, 1973; Slinger, 1977; Muztar et al, 1981), fat utilization (Lall and Slinger, 1973; Slinger, 1977), and body weight gain (Slinger,

1977; Hulan et al, 1984). Hulan et al (1984) also demonstrated that blending rapeseed oil (LEAR) with animal fat improved monetary returns in the broiler industry.

However, blending all oils did not show similar results. It was even shown that not all animal tallows showed synergism when blended with soybean oil (Sibbald et al, 1962). There was no synergism in absorbability when beef tallow and pork lard were blended 1/1 (Fedde et al, 1960), Griffiths et al (1977) reported that corn oil and poultry grease blended (1/1) and fed at 9% of the diet significantly depressed weight gain compared to an isocaloric oil free diet even though feed intake was similar (each oil fed individually increased body weight gains). It was also reported that blending HEAR with soybean oil showed no synergism in poults or chicks (Salmon, 1969a, 1969b) and that blending LEAR with coconut oil or sunflower oil caused no synergism in fat utilization in the rat (Bellenand et al, 1980).

It was also shown that rapeseed oil (both HEAR and LEAR) showed synergistic interactions when blended with tallow, as well as, when blended with the saturated fatty acids (palmitic and stearic in particular) for chicks (Walker et al, 1970; Lall and Slinger, 1973) and rats (Kramer et al, 1981; and Farnworth and Kramer, 1983). Farnworth and Kramer (1983) succeeded in showing that the resulting increased weight gains were due to increased body content of both fat and protein.

These results appeared to indicate that rapeseed oil had a fatty acid composition which was inappropriate for maximal

utilization, and that only relatively specific fatty acid patterns were appropriate. This hypothesis has been supported by Walker et al (1970), Lall and Slinger (1973), Salmon (1977), Sibbald and Kramer (1977), Kramer et al (1981), Mateos and Sell (1981), Farnworth and Kramer (1983) and Hulan et al (1984).

There are 3 prominent hypotheses as to the mechanism of these synergistic interactions. The first, proposed by Walker et al (1970), Lall and Slinger (1973), Salmon (1970, 1977) and Hulan et al (1984), states that blending appropriate fats will produce a fatty acid profile which enhances fatty acid absorption, particularly that of the long chain, saturated palmitic and stearic acids. The second, proposed by Farnworth and Kramer (1983), states that as the dietary fatty acid pattern is altered to resemble that of the adipose tissue, improved growth will result due to reduced metabolic load involved in converting absorbed fatty acids to those appropriate for inclusion in adipose tissue. The third, proposed by Sibbald and Kramer (1977), Mateos and Sell (1981), Muztar et al (1981), Dale and Fuller (1982) and Fuller and Dale (1982), states that the fats and fatty acids interact to allow increased fat absorption and increased absorption of other dietary components. This could possibly be due to increased passage time thruogh the gut (Mateos and Sell, 1981).

Freeman,in his excellent review (1983),states that synergism between fats is highly interactive and its explaination lies in an understanding of digestion and absorption.

Free Fatty Acids

It has long been understood that a confounding factor in oil nutrition experiments has been the variable content of unsaponifiables, steroids, and vitamins. In order to deal with this Hakkarainen et al (1983) suggested feeding hydrolysed soybean oil as a fat source to study vitamin E deficient diets. They observed that this diet (with added fat soluble vitamins) allowed normal growth and developement of White Leghorn chicks. This supported the results of Chen (1979) who observed that free fatty acids (from hydroysed soybean oil) could be utilized by rats which were fed large quantities as the sole source of fat. Chen suggested that this would be useful in studying intestinal re-esterification, fatty acid absorption and lipid metabolism as influenced by dietary fatty acids.

There may, however, be problems associated with this as Carroll and Richards (1958), Renner and Hill (1961a), Swiss and Bayley (1976) and Sklan (1979) reported that feeding free fatty acids (FFA) reduced absorption of fatty acids and total lipid. This is not in agreement with Young (1961), Young and Artman (1961) and Artman (1964) who reported no significant differences in weight gains, feed conversion or fat or energy utilization in chicks fed hydrolyzed oils with practical diets. It was also reported that absorption of FFA was increased by feeding in mixtures rather than feeding single FFAs (Young and Garrett, 1963). Feeding semi-purified diets as Renner and Hill (1961b) and Carroll and Richards (1958) did reduces fatty acid absorption

compared to practical diets (Young et al, 1963). These mixed results indicate that it would be worth re-investigating the value of feeding FFA to assess their usefulness in studying fatty acid absorption.

Physico-chemical properties of oil

It is well known that the polyunsaturated components of fats are oxidized more rapidly than the mono-unsaturated and saturated components (Sonntag, 1979). It is therefore curious that the researchers referenced earlier did not investigate the effects of blending on the oxidative stability of fats, particularly as some suggested that it was economically feasible to blend fats for animal feeds.

This is traditionally done by the measurement of the content of such oxidation products as peroxides, malonic dialdehyde and methyl oleate hydroperoxide by the use of analyses such as the peroxide test and the thiobarbituric acid test (Sonntag, 1979). These tests are applied to oil products in conjunction with an accellerated oxidation test. A simple accellerated oxidation test is the oven or Schaal test, however no standards have been developed for this test, therefore, no comparisons can be made between laboratories (Sonntag, 1979).

Eskin and Frenkel (1977) used these procedures to study the deterioration of hydrogenated soybean and rapeseed (LEAR) oils and concluded that lightly hydrogenated soybean oil was oxidatively more stable than rapeseed oil.

The smoke point is the temperature at which smoking is first

detected in an oil in a laboratory apparatus protected from drafts and provided with illumination. This parameter is little affected by the oil's degree of saturation but depends on the molecular weight and free fatty acid content (Formo, 1979). The Canadian Consumer (1977) reported smoke points of 241°C for soybean oil, 238°C for LEAR, and 246°C for sunflower oil. This reported value for LEAR agreed well with the smoke point of 238°C for LEAR by Ackman (1983) but was significantly higher than the smoke point of 218°C that he reported for HEAR. However, all of these values are well above the 200°C minimum set by the Canadian government for frying oils.

METHODS AND MATERIALS

EXPERIMENTAL ANIMALS

Single Comb White Leghorn cockerels were chosen as the experimental animals for the 3 feeding trials. These were conducted with 3 replicate groups of 10 birds per treatment, which were kept in Petersime battery brooders and provided with 24-hour light. The birds were obtained as day old chicks, weighed and randomly assigned to treatment and cage, where they were raised for a period of 4 weeks. Food and water was provided *ad libitum*.

OILS AND BLENDING

The lipids used were commercially available food grade oils or lard intended for human consumption. The Canbra oil, soybean oil (Maple Leaf Soya Salad Oil) and lard were obtained from Canada Packers Inc. (Toronto and Vancouver). The Canola and sunflower oils were obtained from CSP Foods Ltd. (Saskatoon, Saskatchewan).

To balance the fatty acids lipids were blended in large glass containers by stirring for 15 minutes with a magnetic stirrer. Canbra oil (6.1% erucic acid) was blended with sunflower oil or lard at a ratio of 50/50 (w/w) (Table 1) in Trial 1. Due to the high melting point of the lard it was

Table 1. Fatty Acid Composition of Lipids, Trial 1.

Dietary Oil	Fatty Acid Content (per cent by weight)					
	C14:0[1]	C16:0	C16:1	C18:0	C18:1	C18:2
CBO[2]		3.16	0.23	1.51	53.96	20.41
SFO		6.28		5.46	17.80	66.87
AL	1.21	23.57	2.47	17.68	43.13	8.13
CBO+SFO[3]		4.74		3.71	36.84	42.18
CBO+AL	0.60	13.27	1.33	10.14	48.49	14.12

	C18:3 + C20:0[4]	C20:1	C22:0	C22:1	C24:0
CBO	9.58	3.99		6.13	1.01
SFO	1.04	0.36	1.44	0.27	0.47
AL	1.05	1.43	0.55	0.38	0.40
CBO+SFO	5.46	2.40	1.02	3.20	0.45
CBO+AL	5.17	2.94	0.42	3.03	0.48

[1]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.

[2]CBO = Canbra oil, SFO = Sunflower oil, AL = Animal lard.

[3]Indicates oil blended 1:1 by weight.

[4]The values for linolenic and arachidic acids are combined due to peak overlap on the 15% DEGS packed column.

liquified (50-65°C) before blending. Canola oil (0.55% erucic acid) was blended with graded levels of sunflower oil in reciprocal fashion (Table 2), and 5 blends (9/1, 8/2, 7/3, 6/4, and 5/5) were selected for nutritional assay in Trial 2.

OIL HYDROLYSIS

The free fatty acids of Canola oil, sunflower oil, soybean oil and a 5/5 blend of Canola and sunflower oil used in Trial 3 were produced by alcoholic alkaline hydrolysis as described by Chen (1979). A mixture of 1 kg of oil and 2 litres of 10% NaOH in 70% ethanol was allowed to stand overnight in an Erlenmyer flask. The solution was then neutralized with 2.5 N H_2SO_4 and the fatty acid layer was removed and washed 6 times with warm 3% NaCl. The fatty acid layer was then dehydrated over anhydrous Na_2SO_4.

FEEDING EXPERIMENTS

Trial 1

Five experimental diets were formulated to incorporate either Canbra oil, sunflower oil, animal lard or 1/1 (w/w) blends of Canbra oil and sunflower oil or animal lard into a basal diet (Table 3) at 8%. These experimental diets were assigned randomly in tripicate per treatment to 15 groups of chicks for a 4 week feeding period.

Body weight, weight gain and feed consumption were measured weekly (grams/bird). At the end of 4 weeks feed conversion and apparent feed digestibility were calculated and apparent lipid

Table 2. Fatty Acid Composition of Oils, Trial 2.

Oil Blend	Fatty Acid Content (per cent by weight)					
	C16:0[1]	C16:1	C18:0	C18:1	C18:2	C18:3
CAO[2]	4.33		2.54	60.61	19.90	7.10
9/1[3]	4.44		2.85	57.97	22.51	6.52
8/2	4.52		2.93	56.57	24.24	6.49
7/3	4.97		3.86	48.26	33.03	5.01
6/4	5.22		4.28	44.38	36.99	4.51
5/5	5.38		4.75	39.70	41.98	3.71
4/6	5.57		5.07	35.05	47.13	3.11
3/7	5.83		5.69	30.88	51.79	1.89
2/8	6.03		6.01	26.40	56.79	1.29
1/9	6.29		6.67	22.01	60.88	0.63
SFO	6.51		6.96	17.29	66.03	0.08
SBO	10.93	0.15	5.75	25.80	48.40	6.69

[1]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.

[2]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[3]Indicates Canola and Sunflower oil blended 9/1 (weight/weight).

Continued on next page-

Table 2 (continued).

Oil Blend	Fatty Acid Content (per cent by weight)				
	C20:0	C20:1	C22:0	C22:1	C24:0
CAO	1.24	2.52	0.74	0.55	0.44
9/1	1.25	2.48	0.85	0.54	0.48
8/2	1.17	2.27	0.85	0.50	0.46
7/3	1.05	1.80	1.09	0.43	0.50
6/4	1.00	1.60	1.17	0.37	0.49
5/5	0.96	1.37	1.29	0.32	0.52
4/6	0.87	1.15	1.33	0.27	0.49
3/7	0.68	0.94	1.52	0.22	0.57
2/8	0.62	0.71	1.53	0.15	0.51
1/9	0.63	0.51	1.79		0.58
SFO	0.59	0.29	1.71		0.54
SBO	0.75	0.41	0.83		0.29

[1]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.

[2]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[3]Indicates Canola and Sunflower oil blended 9/1 (weight/weight).

Table 3. Composition of Experimental Basal Diet.

Ingredient	Percent
Ground wheat (12.5% protein)	59.65
Soybean meal (44.5% protein)	29.00
Calcium multiphosphate	1.75
Limestone	0.60
Vitamin premix[1]	0.50
Mineral premix[2]	0.50
Lipid	8.00
Calculated Analysis	
Constituent	Amount
Crude protein	20.40%
Crude lipid	9.33%
Metabolizable energy	2,895 kcal/kg
Calcium	0.90%
Phosphorus	0.70%
Lysine	1.08%
Methionine	0.38%

[1]Supplies per kilogram of feed: Vitamin A, 8800 IU; Vitamin D_3, 880 ICU; Vitamin E, 22 IU; Vitamin B_{12}, 13.2 mcg; Riboflavin, 6.6mg; Calcium pantothenate, 8.8 mg; Niacin, 22 mg; Choline chloride, 220 mg; Amprolium, 124.9 mg; Bacitracin, 9.7mg, and Santoquin, 454 mg in a corn starch, wheat carrier.

[2]Supplies per kilogram of feed: Mn, 55 mg; Zn, 40 mg; and Cu, 4.0 mg in an iodized NaCl carrier.

absorption, apparent total fatty acid absorption and apparent individual fatty acid absorption were determined.

Trial 2

Eight experimental diets were formulated to incorporate either Canola oil, sunflower oil, soybean oil, or Canola oil and sunflower oil blended in the proportions 9/1, 8/2, 7/3, 6/4 and 5/5 (w/w) into a basal diet (Table 3) at 8%. The experimental diets were assigned to 24 groups of chicks as described in Trial 1.

Body weight, weight gain and feed consumption were measured weekly (grams/bird). At the end of the 4th week feed conversion and apparent feed digestibility were calculated and apparent lipid absorption, apparent total fatty acid absorption, apparent individual fatty acid absorption, nitrogen retention and diet metabolizable energy were determined.

Trial 3

This experiment was designed to determine the feasibility of feeding hydrolyzed oils to eliminate the confounding factors of steroids, vitamins, and triglycerides on fatty acid absorption. Four experimental diets were formulated to incorporate either the hydrolyzed Canola oil, soybean oil , sunflower oil or a 5/5 blend of Canola and sunflower oil into a basal diet (Table 3) at 8%. The experimental diets were randomly assigned to 12 groups of chicks in triplicate per treatment for a 4 week feeding period. The results were compared with the results of the intact oils used in Trial 2.

Body weight, weight gain and feed consumption were measured

weekly (grams/bird). At the end of 4 weeks feed conversion and apparent feed digestibility were calculated and apparent lipid absorption, apparent total fatty acid absorption and apparent individual fatty acid absorption were determined.

DIGESTIBILITY

After the 4th week of the feeding period 4 birds were randomly selected from each group and given a marker diet to facilitate a total fecal collection in order to determine feed digestibility, apparent lipid absorption, apparent total fatty acid absorption and apparent individual fatty acid absorption.

Fecal collection

In all cases the marker diet was the treatment diet to which 0.5% ferric oxide had been added. This diet was provided for twelve hours after which the unmarked diet was again provided for a period of 24 hours during which consumption was measured. After this the marked diet was given again for another 12 hours. This resulted in feces which could be visually identified on the basis of ferric oxide content. The birds were then removed and the feces air dried for a period of 24 hours in the brooders. The unmarked feces were then manually separated from the marked feces and placed in a dessicator. They were then ground with a microgrinder and stored in a dessicator.

Dry matter

The % dry matter of the feces and feed was determined at the time of lipid extraction by weighing duplicate samples and placing them in a drying oven for 48 hours at 80°C, followed by

cooling for 5 hours in a dessicator prior to determining moisture loss. All calculations and results are presented on a dry matter basis.

Apparent digestibility calculation

The apparent digestibility or absorption of all nutrients were calculated by the formula:

$$\% \text{ Absorption} = \frac{\text{Intake} - \text{Excretion}}{\text{Intake}} \times 100$$

Dietary intake of individual fatty acids was determined on the basis of the analyzed fatty acid profile of the diet and not the oil. These fatty acid profiles are given in Appendix B, (Tables II, III and IV).

METABOLIZABLE ENERGY

In Trial 2, the apparent nitrogen retention was calculated from the nitrogen content of feed and feces as determined by the macro Kjeldahl method (AOAC, 1980), and the gross energy of the feed and feces was determined by oxygen bomb calorimetry using a Parr Oxygen Bomb Calorimeter. These values were used to calculate the apparent metabolizable energy (nitrogen corrected) of the diets as described by Sibbald (1979), using the formula:

$$\text{AMEn/g of feed} = \frac{[(FI \times GEF) - (E \times GEE)] - (NR \times K)}{FI}$$

Where $NR = (FI \times NF) - (E \times NE)$

FI = feed intake (g)

E = excreta output (g)

GEF = gross energy/g of feed

GEE = gross energy/g of excreta

NF = nitrogen/gram of feed

NE = nitrogen/gram of excreta

K = 8.22 Kcal (Hill and Anderson, 1958)

FATTY ACID ANALYSIS

Lipid extraction

Lipids were extracted by a modification of the method of Folch et al (1957). Approximately 5 grams of homogenized sample (feed or feces) were placed into Erlenmyer Flasks. Total lipids were then extracted overnight with Folch reagent (15 ml of 2:1 v/v chloroform:methanol solution/gram of sample). In the case of fecal samples the Folch reagent was acidified by the addition of 2% concentrated formic acid to hydrolyse soaps as described by Savary and Constantin (1966). The extract was filtered on Whatman No. 1 filter paper into a graduated cylinder, washed with saline solution and the phases allowed to separate. The upper phase, containing water, methanol and water soluble material was siphoned off and discarded. The lower phase of chloroform and lipids was further washed with a chloroform:methanol:saline (3:47:48 v/v) solution. Again, the phases were allowed to separate. The final volume of the lower chloroform:lipid layer was recorded and the upper layer siphoned off and discarded. Three aliquots of the chloroform layer were then taken for determination of % lipid, % total fatty acid, and preparation of methyl esters of the fatty acids for Gas Liquid Chromatography (GLC).

Total lipid and fatty acid determination

Total lipid was determined by taking a 5.0 ml aliquot of the chloroform layer and placing it in a tared aluminum weighing dish, evaporating it under a stream of nitrogen, and placing in a drying oven at 65-70° C over night. The samples were then cooled in a dessicator for 5 hours and the sample weight recorded and % total lipid calculated.

Percent total fatty acid was determined by a modified AOAC (1980) method. A 10 ml aliquot of the Folch extract was placed in a screw-top culture tube (with teflon lined caps). This sample was evaporated under a nitrogen stream and the dry lipids were saponified with 4.0 ml 0.5 M methanolic KOH on a 50° C water bath over 50 minutes. Then the solution was extracted twice with 5 ml petroleum ether to remove the unsaponifiable fraction. The soap was then hydrolyzed with 2 ml of 1 M HCl and 1 ml distilled H_2O and 5 ml petroleum ether was added to the resulting biphasic solution. The solution was then centrifuged for 20 minutes to pack the interfacial "fluff" and the ether layer was transfered to dry, preweighed aluminum dishes and treated as described for total lipids and % total fatty acids was calculated.

Fatty acid derivitization

The methyl esters of the fatty acids were produced by a modified AOCS (1980) method. Enough Folch extract to provide 250-300 mg of lipid was placed in a screw cap culture tube. This sample was evaporated under a nitrogen stream. Then 4.0 ml of 0.5 M methanolic NaOH was added and the solution was incubated at

70°C for 10 minutes in a water bath. To this solution 5.0 ml of 14% boron trifluoride was added and the cap was loosely placed on the tube and this was placed back in the water bath for 1 hour. At this point the cap was tightened and the tube was placed in an oven at 65-70° C for 12 hours. Then 3 ml of heptane was added and the solution was vigorously shaken and allowed to stand until the layers separated. The heptane layer was then dried over a 4:1 mixture of anhydrous Na_2SO_4:Na_2CO_3 and a portion transferred to septum vials which were stored under nitrogen and refrigeration until analysis.

Gas liquid chromatography

The fatty acid composition of the lipids was determined using a Varian Gas Liquid Chromatograph, model 3700, equipped with a flame ionization detector, 2 meter (3.18 mm inside diameter) packed column, and a Vista 400 data processor. In Trial 1 the stationary phase used for the determination of the lipid fatty acids (table 3) was 15% Diethylene Glycol Succinate Polyester on Chromasorb Q (mesh size 80/100 M) and the runs were temperature programed from 160-190° C with an initial time of 7 minutes, a program rate of 5° C/minute and a final time of 47 minutes. Injector and detector temperatures were 200 and 230°c, respectively, and the nitrogen flow rate was 30 ml/minute. In all subsequent determinations the packing material was 10% Silar 5CP (stationary phase) on Chromosorb Q (mesh size 80/100). The runs were temperature programed over a temperature range of 160- 230° C, with an initial time of 7 minutes, a program rate of 10 °C/minute and a final time of 26 minutes.

Injector and detector temperatures were 250 and 300°C, respectively, and the nitrogen flow rate was 30 ml/minute.

Fatty acid identification

Identification of fatty acids was accomplished by comparison of the chromatogram peak retention times with those of fatty acid standards. Percent composition of fatty acids were calculated as the ratio of peak area to total chromatogram area by the Vista 400 data processor. These percent compositions were later converted to percent by weight by the formula:

$$\% \text{ Fatty Acid by Weight} = \frac{\% \text{ FA} \times \text{MW}}{\text{Sum of Wt of the FA Present}} \times 100$$

Where: FA = Fatty Acid

MW = Molecular Weight

PHYSICO-CHEMICAL DETERMINATIONS

Oven test

The deterioration study was modelled after a study published by Eskin and Frenkel, 1977. It was conducted on 300 ml samples of oil which were placed in clean 600 ml Pyrex beakers which contained Teflon coated magnetic stirrers. The mouth of the beakers were covered with a 75 mm diameter watch glass and placed in an oven at 70°C. The beakers were removed from the oven at 0, 2, 5, 8, 12, and 16 days of incubation. At this time the oil was mixed with the magnetic stirrers for 1 minute to homogenously distribute the oxidation products and to change the interface, and duplicate samples for peroxide value and thiobarbituric

acid value determination were taken. These samples were stored in glass scintillation vials under nitrogen at -25°C until analysis.

Peroxide and thiobarbituric acid values

Peroxide values were determined by Official Method Cd 8-53 (AOCS, 1980). Thiobarbituric acid values were determined by a method modified after Sidwell et al, 1954. Oil (3.0 grams) was weighed into a screw cap tube to which 10 ml CCl_4 and 10 ml thiobarbituric acid reagent was added. The tube was capped with a Teflon lined cap and placed on a horizontal shaker with a 3.18 cm oscillation for 4 minutes. The aqueous layer was then transfered to a test tube and immersed in a boiling water bath for 30 minutes. The solution was then cooled and a portion transfered to a cuvette and the absorbancy was read at 530 nm against distilled water.

Smoke point

Smoke points were determined by a modified Official Method Cc 9a-48 (AOCS, 1980). A Cleveland open flash cup was filled with the oil so that the top of the meniscus touched the filling line. It was then placed in a 46x51x44 cm illuminated cabinet and a thermometer was suspended in a vertical position in the center of the cup with the bottom of the bulb about 6.35 mm from the bottom of the cup. The sample was then heated with a bunsen burner so that the temperature of the sample increased at about 5-6°C per minute. The smoke point was taken as the temperature indicated by the thermometer when the sample gave off a thin, continuous stream of bluish smoke.

STATISTICS

Data for the 3 feeding trials were tested for significance by analysis of variance and means were compared by Duncan's New Multiple Range Test as described by Steel and Torrie (1980). Percentage data were treated with the arcsine transformation prior to analysis and missing values were calculated by the method recommended by Steel and Torrie (1980).

RESULTS AND DISCUSSION

TRIAL 1

Chick performance

The dietary oils used in this experiment significantly ($P < 0.05$) affected body weight, weight gain and feed consumption but not on feed conversion (Table 4). In terms of body weight and weight gain Canbra oil was equivalent to lard in growth promotion but both were significantly ($P < 0.05$) inferior to sunflower oil in this respect. This agrees with the report of Clandinin *et al* (1978) which indicated that LEAR (2.5% erucic acid) was inferior to sunflower oil in terms of growth promotion, stimulation of feed consumption and energy utilization. The blended oils were not significantly ($P < 0.05$) different from the sunflower oil treatment in either final body weight or weight gain. However, these body weights tended to be somewhat smaller than those of the sunflower oil fed groups (Table 4). The Canbra oil/lard blend showed definite synergism in weight gain as has often been reported (Lall and Slinger, 1973; Slinger, 1977; Hulan *et al*, 1984). On the other hand, the Canbra oil/sunflower oil blend did not show any synergism in body weight or weight gain as the average weight gain of the birds was only slightly above the arithmetic mean of the average weight gains of the birds in the Canbra oil and sunflower oil treatments. This agrees with the report of Bellenand *et al*

Table 4. Effect of Oil Blending on the Growth Performance of Chicks at 4 weeks, Trial 1.

Dietary Oil[1]	Chick Performance[2]			
	Body weight (g/bird)	Weight gain (g/bird)	Feed Consumed (g/bird)	Feed Conversion (g consumed/gain)
CBO	299.2[a]	262.0[a]	548.1[a]	2.09
SFO	322.3[c]	285.0[c]	595.8[b]	2.10
AL	304.8[a-b]	268.1[a-b]	577.7[b]	2.16
CBO+SFO[3]	313.8[b-c]	277.2[b-c]	574.6[a-b]	2.07
CBO+AL	319.5[c]	283.1[b-c]	587.9[b]	2.08
SEM[4]	4.53	4.45	9.11	0.02

[1]CBO = Canbra oil, SFO = Sunflower oil, AL = Animal lard.

[2]Means followed by the same superscript are not significantly different ($P < 0.05$).

[3]Oils blended 1:1.

[4]Standard error of the mean (n = 3).

(1980).

The Canbra oil treatment resulted in significantly ($P < 0.05$) less feed consumption than any of the other treatments except the Canbra oil/sunflower oil blend which was not significantly different from either the Canbra oil treatment or the other treatments in this respect.

Interestingly there was a strong correlation between the feed consumption and weight gains in these treatments ($r=0.90$). This seems to support the reports of Joshi and Sell (1964) and Alexander and Mattson (1966) who indicated that depressed feed consumption was the primary cause of weight gain depression observed in diets containing rapeseed oil.

The feed conversion data shows no significant differences between treatments. However, both blended oils showed a trend toward synergistic improvement in feed conversion. These result agree with the results of Hulan et al (1984) who proposed that the fatty acid profile of an oil may alter the metabolism of chickens, particularly in intestinal absorption of fatty acids.

Apparent digestibility coefficients

The apparent digestibility coefficients of feed and total fatty acids demonstrated no significant ($P < 0.05$) differences between treatments (Table 5). The digestibility of the total lipid in the Canbra oil treatment was significantly ($P < 0.05$) lower than in the other treatments. There was a synergistic increase in the total lipid digestibility of the Canbra oil/sunflower oil blend and the total fatty acid digestibility of both blends also showed this trend. The total fatty acid

Table 5. Apparent Digestibility Coefficients at 4 Weeks, Trial 1.

Dietary Oil	Apparent Digestibility Coefficient[1]		
	Feed	Total lipid	Total fatty acid
CBO[2]	79.56	87.21[a]	89.71
SFO	79.14	89.05[b]	91.76
AL	81.29	90.22[b]	90.67
CBO+SFO[3]	79.62	90.02[b]	92.86
CBO+AL	78.83	89.39[b]	92.01

[1]Means followed by the same superscript are not significantly different ($P < 0.05$), analysis was performed on transformed data.

[2]CBO = Canbra oil, SFO = Sunflower oil, AL = Animal lard.

[3]Oils blended 1:1.

digestibility also correlated well with weight gain (r=0.80). These results indicate that something other than feed consumption may affect the growth performance of the chicks.

Apparent individual fatty acid absorption

The individual fatty acid absorption data (Table 6) agrees well with the total lipid and total fatty acid data presented earlier. That is, with the exception of C18:1, C18:3 and C20:1 (which make up a relatively small portion of the oil) the absorption values of the Canbra oil are inferior to those of the sunflower oil. The lard shows poor absorption of C18:2 and C18:3 (87.23% and 81.55% respectively) but a high absorption of C16:0. The high degree of absorption of the C16:0 in lard has been well documented and is attributed to its preferential incorporation into the beta position on the triglyceride molecule (Renner and Hill, 1960; Whitehead and Fisher, 1975).

A positive synergistic increase in the absorption of all of the individual fatty acids was seen in both blends with the only exception being found in the C18:2 of the Canbra oil/animal lard blend.

These results indicate that Canbra oil fatty acids are imbalanced for maximum absorption as suggested by Walker et al (1970), Lall and Slinger (1973) and Hulan et al (1984). These workers all suggested that rapeseed oils were deficient in the long chain saturated fatty acids. While this hypothesis would explain the synergism observed in the Canbra oil/animal lard blend it does not explain the synergistic effects of the Canbra oil/sunflower oil blend. Indeed Beare-Rogers (1977)

Table 6. Apparent Individual Fatty Acid Absorption, Trial 1.

Dietary Oil	Apparent Fatty Acid Absorption[1] (per cent)			
	C16:0[2]	C18:0	C18:1	C18:2
CBO[3]	81.08[a]	79.68[a]	92.17[a,b]	88.40[a]
SFO	86.41[b]	90.32[b]	90.54[a]	93.76[b]
AL	91.82[c]	82.58[a]	94.34[b]	87.23[a]
CBO+SFO[4]	86.60[b]	91.55[b]	94.11[b]	93.06[b]
CBO+AL	90.86[c]	92.53[b]	94.24[b]	87.36[a]

	C18:3	C20:1	C22:1
CBO	92.09[c]	87.72[a,b]	87.03
SFO	72.77[a]	82.60[a]	
AL	81.55[b]	90.35[b,c]	
CBO+SFO	91.27[c]	93.33[c]	93.06
CBO+AL	90.70[c]	92.75[b,c]	92.69

[1]Means followed by the same superscript are not significantly different ($P<0.05$), analysis was performed on transformed data.

[2]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.

[3]CBO = Canbra oil, SFO = Sunflower oil, AL = Animal lard.

[4]Indicates oil blended 1:1 by weight.

quotes Rocquelin and Cluzan as stating that the ratio of saturated to unsaturated fatty acids in an oil is unimportant in utilization when the oil contains more than 10% linoleic acid. This research clearly supports this view. Canbra oil utilization can be improved by blending with either lard (saturated fat) or sunflower oil (highly unsaturated oil). These results point toward a much more complex interaction of fatty acids than was previously postulated and indicates that continued research in this area could very well prove productive.

TRIAL 2

There was no significant difference between the final body weights of the birds fed Canola oil, sunflower oil or soybean oil (Table 7). This agrees with the data of March (1977) for chickens and Beare-Rogers et al (1979) and Ziemlanski (1977) for rats. However, Clandinin et al (1978) reported that LEAR was inferior to sunflower oil in promoting chick growth and Kramer et al (1973), Kramer et al (1981) and Farnworth and Kramer (1983) reported that soybean oil promoted significantly more growth than LEAR (0.6% erucic acid). However, all blends except 8/2 and 6/4 showed synergistic increases in final body weight. This pattern was also shown in the weight gains of the birds (Table 7). The largest weight gain was demonstrated by the 7/3 blend, although this was not significantly ($P < 0.05$) greater than that demonstrated by the Canola oil, 9/1, 6/4 and 5/5 treatments it was significantly ($P < 0.05$) greater than the weight gains of either the sunflower or soybean oil treatments. This would indicate a real improvement in the ability to support chick growth over both Canola oil and sunflower oil fed individually. The weight gain data for the 8/2 blend appeared to be considerably lower than expected when compared with all of the other treatments containing Canola oil. This result could not be logically explained except as a random event with a probability of less than 5%. Therefore, another feeding trial was set up (see appendix A) to determine whether or not this result was repeatable and to directly compare Canbra and

Table 7. Effects of Oil Blending on the Growth Performance of Chicks at 4 Weeks, Trial 2.

Dietary Oil	Chick Performance[2]			
	Body weight (g/bird)	Weight gain (g/bird)	Feed Consumed (g/bird)	Feed Conversion (g consumed/gain)
CAO[1]	332.1^{abc}	292.0^{abc}	599.7	2.05
9/1[3]	336.5^{bc}	296.8^{bc}	604.7	2.04
8/2	308.6^{a}	269.0^{a}	560.2	2.08
7/3	343.1^{c}	303.4^{c}	631.3	2.08
6/4	323.8^{abc}	284.1^{abc}	604.1	2.13
5/5	332.7^{abc}	292.8^{bc}	613.7	2.10
SFO	310.4^{a}	270.6^{a}	575.9	2.14
SBO	314.7^{ab}	274.7^{ab}	586.9	2.14
SEM[4]	7.29	7.21	17.08	0.03

[1]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil

[2]Means followed by the same superscript are not significantly different ($P < 0.05$).

[3]Indicates Canola and Sunflower oil blended 9/1 (weight/weight).

[4]Standard error of the mean (n = 3).

Canola oil. The results of this trial confirmed the results of earlier trials for chick growth supported by Canbra, Canola, sunflower, and the 7/3 blend. However the weight gains for the 8/2 blend were considerably increased indicating that the low weight gains for this blend in Trial 2 were probably random.

Table 7 also shows that there were no significant differences in feed consumption for any of the treatments used in this trial. This would seem to concretely support the theory that the differences in weight gain are due to different nutritive properties of the oils and blends. However, there was a strong correlation (r=0.94) between feed consumption and weight gain. The correlation implies that there were actual consumption differences but that the experimental design did not allow enough precision to detect them. This conclusion was also supported by the feeding trial described in Appendix A. These results support the theory that consumption is the major factor in growth depression caused by early rapeseed oils (Joshi and Sell, 1964; Alexander and Mattson, 1966). But it does not exclude the possibility of an unbalanced fatty acid profile as shown by the synergistic interactions in both final body weight and weight gain seen in this study. It therefore appears that there was an interaction between consumption and other factors which were all related to weight gain.

There was no significant differences in feed conversion as was reported by Joshi and Sell (1964), however, Salmon (1969b) and Hulan et al (1982) reported increased feed conversion caused by rapeseed oil compared to soybean oil. The values for

this parameter ranged from a high of 2.14 for both sunflower and soybean oil and a low of 2.04 for the 9/1 blend with the others falling in between (Table 7). This data shows a trend toward improvement in feed conversion for the 9/1, 8/2 and 7/3 blends in spite of the lack of significance.

Apparent digestibility coefficients

Significant differences in feed digestibilities due to oil type were apparent. There was no significant difference between feed digestibility for the Canola oil and sunflower oil but the soybean oil treatment showed significantly ($P < 0.05$) higher feed digestibility (Table 8). All blends except 9/1 showed synergistic increases in feed digestibility when compared to the Canola and sunflower oils. The 7/3 blend was significantly higher in feed digestion promotion than the sunflower oil but was not different from the Canola oil. The other blends were not different from either the Canola oil or the sunflower oil in this respect. Three of the blends (7/3, 6/4 and 5/5) had feed digestibilities statistically similar to that of soybean oil.

Total lipid digestibility of the 9/1 blend was significantly lower ($P < 0.05$) than the other treatments (Table 8), the reason for this is not readily apparent. The total fatty acid digestibility showed no significant differences between treatments but followed the same trend as the feed digestibility.

Data pertaining to nitrogen retention relative to dietary oil are also summarized in Table 8. The nitrogen retention in the Canola and soybean oil treatments were not significantly different although the soybean result was considerably higher.

Table 8. Apparent Digestibility Coefficients at 4 Weeks, Trial 2.

Dietary Oil	Apparent Digestibility Coeffiecents[1]			
	Feed	Total lipid	Total fatty acid	N retention
CAO[2]	80.07^{ab}	88.90^{b}	89.31	69.40^{ab}
9/1[3]	79.07^{a}	83.84^{a}	89.50	66.20^{a}
8/2	80.08^{ab}	90.96^{b}	89.33	67.34^{a}
7/3	83.95^{bc}	92.59^{b}	93.15	75.07^{b}
6/4	80.59^{abc}	88.94^{b}	89.19	67.54^{a}
5/5	81.97^{abc}	91.70^{b}	91.94	71.93^{ab}
SFO	79.14^{a}	89.68^{b}	90.43	66.75^{a}
SBO	84.17^{c}	91.23^{b}	91.16	75.32^{b}

[1]Means followed by the same superscript are not significantly different ($P < 0.05$), analysis was performed on transformed data.

[2]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[3]Indicates Canola and Sunflower oil blended 9/1 (weight/weight).

Similarly there was no difference between the Canola and sunflower treatments although the sunflower treatment was significantly lower ($P < 0.05$) than the soybean oil treatment. The blended treatments show no synergistic effects in nitrogen retention except in the 7/3 and 5/5 blends which were not significantly different than either the Canola oil treatment or the soybean oil treatment. The 7/3 blend however, was equivalent to the soybean oil with nitrogen retentions of 75.07 and 75.32 per cent, respectively.

The above result is supported by Farnworth and Kramer (1983) who reported that blending LEAR resulted in improved growth, and increased body fat and protein in rats. These results also support the hypothesis that fats and fatty acids interact to allow increased fat absorption and absorption of other dietary components (Sibbald and Kramer, 1977; Mateos and Sell, 1981; Muztar et al, 1981; Dale and Fuller, 1982; Fuller and Dale, 1982).

Apparent metabolizable energy of the diets

The nitrogen corrected apparent metabolizable energy (AMEn) of the diets are shown in Table 9. It can be seen that the soybean oil diet had a significantly ($P < 0.05$) higher AMEn than either the Canola oil or the sunflower oil diets which had roughly equivalent values. The 7/3, 6/4 and 5/5 blends again showed a synergistic interaction with 7/3 having the highest AMEn, which was equivalent to that of the soybean oil.

The results agree well with those of Sell and Hodgson (1962) who reported that there was no significant difference in ration

Table 9. Apparent Metabolizable Energy of Diets (Nitrogen Corrected), Trial 2.

Oil Type	AMEn[1] (Kcal/kg)
CAO[2]	4082.39[a]
9/1[3]	4044.85[a]
8/2	4067.77[a]
7/3	4265.11[bc]
6/4	4107.52[ab]
5/5	4174.85[abc]
SFO	4097.40[a]
SBO	4281.50[c]
SEM[4]	50.93

[1]Means followed by the same superscript are not significantly different ($P < 0.05$).

[2]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[3]Indicates Canola and Sunflower oil blended 9/1 (weight/weight).

[4]Standard error of the means (n = 3).

M.E. of chicken diets containing 8% rapeseed oil or sunflower oil but that diets containing 8% soybean oil had significantly higher M.E. Joshi and Sell (1964) reported similar results for turkey poults although in this case the diet M.E. was similar for the sunflower and soybean treatments and significantly lower for rapeseed oil diets. This difference was also reported by Salmon (1969a) for turkey poults, although he reported (1969b) no difference in diet M.E. for chickens fed diets containing rapeseed oil or soybean oil. It should be noted however, that only Salmon reported the erucic acid content of his rapeseed oil (which was HEAR).

The differences in AMEn found in this experiment also supports the data presented earlier in which total diet digestibility and nitrogen retention were improved by blending oil. That is, AMEn correlates strongly with diet digestibility (r=0.97), nitrogen retention (r=0.96), total fatty acid digestibility (r=0.78) and total lipid digestibility (r=0.71), but correlates poorly with weight gain (r=0.17). These correlations indicate that the dietary fatty acid profile affects AMEn, the absorption of the total diet, nitrogen retention and fat absorption but that feed consumption is the over-riding factor in chick weight gain.

Apparent Individual fatty acid absorption

As can be seen in Table 10 only 5 fatty acids (C16:0, C18:2, C18:3, C20:1 and C24:0) were significantly ($P < 0.05$) affected by the various treatments. Of these fatty acids the absorption was higher in those derived from soybean oil than those from Canola

Table 10. Apparent Individual Fatty Acid Absorption, Trial 2.

Dietary Oil	Apparent Fatty Acid Absorption[1] (per cent)				
	C16:0[2]	C18:0	C18:1	C18:2	C18:3
CAO[3]	81.99[a]	81.97	91.71	87.61[a]	92.30[a-b]
9/1[4]	83.80[a-b]	82.76	91.39	88.72[a]	92.01[a-b]
8/2	83.41[a-b]	83.21	91.27	89.10[a]	91.72[a-b]
7/3	88.63[c]	90.62	94.50	93.03[c]	94.41[d]
6/4	81.70[a]	85.63	90.88	89.88[a-b]	90.69[b]
5/5	86.80[b-c]	88.58	93.07	92.63[c]	92.93[b-c-d]
SFO	85.60[a-b-c]	87.65	89.63	91.96[b-c]	82.36[a]
SBO	88.40[c]	85.70	91.40	92.32[b-c]	93.58[c-d]

[1]Means followed by the same superscript are not significantly different ($P<0.05$), analysis was performed on transformed data.

[2]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.

[3]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[4]Indicates Canola and Sunflower oil blended 9/1 (weight/weight).

Continued on next page-

Table 10 (continued).

Dietary Oil	Apparent Absorption (per cent)				
	C20:0	C20:1	C22:0	C22:1	C24:0
CAO	82.28	86.08[ab]	72.67	77.87	75.27[ab]
9/1	80.97	87.29[ab]	75.75	79.19	81.83[bcd]
8/2	81.73	85.44[a]	72.38	75.73	77.16[ab]
7/3	89.27	91.05[b]	85.19	85.70	86.92[cd]
6/4	80.32	83.91[a]	73.69	72.30	71.30[a]
5/5	85.98	88.05[ab]	82.96	77.86	75.97[ab]
SFO	80.52	82.69[a]	79.82	73.27	80.26[abc]
SBO	83.18	83.15[a]	74.43		88.45[d]

[1]Means followed by the same superscript are not significantly different ($P<0.05$), analysis was performed on transformed data.

[2]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.

[3]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[4]Indicates Canola and Sunflower oil blended 9/1 (weight/weight).

oil except C20:1. When compared with sunflower oil, the absorption of these individual fatty acids were equivalent in all except C18:3 and C24:0 which showed greater absorption in the soybean oil treatment. As for the comparison of the sunflower oil and Canola oil treatments, the absorption of these 5 fatty acids were statistically equivalent except for the C18:3 which showed particularly low absorption in the sunflower oil treatment. This may have been due to the high level of C18:2 in the sunflower oil diet as this fatty acid appears to inhibit the absorption of C18:3 (Chow and Hollander, 1979).

The blended treatments 7/3 and 5/5 showed marked synergistic improvments in individual fatty acid absorption. All individual fatty acids derived from these 2 blends except the C24:0 were as absorbable as those of the soybean oil treatment. The synergistic increase in absorption was particularly noticable in the essential fatty acids (C18:2 and C18:3). Blending the oils improved the absorption of most of the individual fatty acids, especially in the 7/3 and 5/5 blends. The results agree with the earlier reports of increased saturated fatty acid utilization due to blending (Young and Garrett, 1963; Artman, 1964) and increased total fat utilization (Lall and Slinger, 1973; Slinger, 1977).

TRIAL 3

Chick performance

This experiment was designed to compare the effects of feeding hydrolysed oils with their intact counter parts. Table 11 shows that feeding practical diets containing hydrolyzed oils (free fatty acid mixtures) has no significant ($P < 0.05$) effects on body weight, weight gain, feed consumption or feed conversion compared to diets containing intact oils. However, except for the sunflower oil treatments, the birds tended to consume less feed and gain less weight (but not significantly) when fed hydrolyzed fatty acids. This agrees with the data presented by Young (1961), Young and Artman (1961), Artman (1964) and Hakkarainen et al (1983) for chicks and Chen (1979) for rats. The feed conversion ratio tended to decrease when free fatty acids were fed to the chicks except in the case of the Canola oil treatment. However, the reverse trend was reported by Young and Artman (1961) and Artman (1964).

Apparent digestibility coefficients

The data in Table 12 shows that feeding hydrolyzed oil had no significant effect on feed digestibility when compared to intact oils except in the case of the hydrolyzed soybean oil which significantly ($P < 0.05$) reduced the digestibility of the diet. This same pattern was shown in the total lipid digestibility, however another trend emerged in this data. All of the hydrolyzed oil treatments were lower in total lipid digestibility than their corresponding intact oil. These results agree well with the observations reported by Renner and Hill

Table 11. Effect of Free Fatty Acids on the Growth Performance of Chicks at 4 Weeks, Trial 3.

Dietary Oil	Chick Performance[1]			
	Body weight (g/bird)	Weight gain (g/bird)	Feed Consumed (g/bird)	Feed Conversion (g consumed/gain)
CAO[2]	332.1	292.0	599.7	2.05
CAO FFA[3]	316.9	278.2	591.9	2.13
SFO	310.4	270.6	575.9	2.14
SFO FFA	320.5	281.0	582.1	2.08
5/5[4]	332.7	292.8	613.7	2.10
5/5 FFA	317.8	279.6	565.8	2.02
SBO	314.7	274.7	586.9	2.14
SBO FFA	303.6	264.6	554.7	2.09
SEM[5]	9.10	9.00	24.70	0.03

[1]Means followed by the same superscript are not significantly different ($P < 0.05$).

[2]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[3]CAO FFA indicates free fatty acids of Canola oil.

[4]Indicates Canola and Sunflower oil blended 5/5 (weight/weight).

[5]Standard error of the means (n=3).

Table 12. Apparent Digestibility Coefficients at 4 Weeks, Trial 3.

Dietary Oil	Apparent Digestibility Coeffiecents[1]		
	Feed	Total lipid	Total fatty acid
CAO[2]	80.07[a]	88.90[b]	89.31
CAO FFA[3]	81.70[ab]	88.77[b]	88.49
SFO	79.14[a]	89.68[b]	90.43
SFO FFA	81.45[ab]	88.99[b]	89.91
5/5[4]	81.95[ab]	91.20[b]	91.94
5/5 FFA	79.67[a]	87.70[ab]	88.63
SBO	84.17[b]	91.23[b]	91.16
SBO FFA	80.28[a]	84.21[a]	85.42

[1]Means followed by the same superscript are not significantly different ($P < 0.05$), analysis was performed on transformed data.

[2]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[3]CAO FFA indicates free fatty acids of Canola oil.

[4]Indicates Canola and Sunflower oil blended 5/5 (weight/weight).

(1961a) and Sklan (1979) that total fatty acids from hydrolyzed soybean oil were less absorbable than those of intact oil. However, Young (1961), reported that feeding hydrolyzed soybean or corn oil had no effect on their absorbability. Young and Artman (1961) reported that hydrolysis of soybean oil or animal fat reduced their digestibility but not to the degree reported by Renner and Hill. Artman (1964) also reported a trend toward slight decreases in the digestibilities of soybean oil, tallow and blends of tallow when these fats were hydrolyzed. These results support the sunflower oil, Canola oil and oil blend results obtained in this experiment. The reason for the differences in response of the oil types is at this point unclear. It appears that the chick's response to hydrolysed oils may be more variable than their response to intact oils. This may partially explain the variability in the results reported in the literature and the results of this experiment.

Apparent Individual fatty acid absorption

The hydrolyzed oil treatments resulted in significant ($P < 0.05$) differences in the absorption of only 4 fatty acids. These were C18:1, C18:2, C18:3 and C24:0 (Table 13). There were no significant differences in the absorption of the fatty acids when the chicks were fed with either Canola oil or hydrolyzed Canola oil. There did appear to be a pattern though. All of the fatty acids except the 18 carbon chain ones showed slight increases in absorption and the 18 carbon fatty acids showed slight decreases in the hydrolyzed treatments. This was also true of the sunflower treatments with the exception of C24:0 which showed a

Table 13. Apparent Individual Fatty Acid Digestibility, Trial 3.

Dietary Oil	Apparent Fatty Acid Digestibility[1] (per cent)				
	C16:0[2]	C18:0	C18:1	C18:2	C18:3
CAO[3]	81.99	81.95	91.71^{bc}	87.61^{a}	92.30^{d-e}
CAO FFA[4]	82.59	83.00	90.07^{b-c}	87.41^{a}	90.77^{c-d}
SFO	85.60	87.65	89.63^{b-c}	91.96^{b-c}	82.36^{a}
SFO FFA	86.76	88.27	89.25^{b}	90.99^{b-c}	85.32^{a-b}
5/5[5]	86.80	88.58	93.07^{a}	92.63^{c}	92.93^{d-e}
5/5 FFA	84.06	85.89	89.62^{b-c}	89.28^{a-b}	89.54^{c}
SBO	88.40	85.70	91.40^{b-c}	92.32^{c}	93.58^{e}
SBO FFA	82.63	78.84	84.60^{a}	86.16^{a}	88.26^{b-c}

[1]Means followed by the same superscript are not significantly different ($P<0.05$), analysis was performed on transformed data.

[2]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.

[3]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[4]FFA indicates free fatty acids.

[5]Indicates Canola and Sunflower oil blended 5/5 (weight/weight).

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Table 13 (continued).

Dietary Oil	Apparent Digestibility (per cent)				
	C20:0	C20:1	C22:0	C22:1	C24:0
CAO	82.28	86.08	72.67	77.87	75.27[ab]
CAO FFA	84.48	86.86	79.24	82.54	88.85[ab]
SFO	80.52	82.69	79.82	73.27	80.26[ab]
SFO FFA	82.88	85.05	83.84	69.59	95.17[c]
5/5	85.98	88.05	82.96	77.86	75.60[ab]
5/5 FFA	83.26	85.06	81.21	78.03	82.99[ab]
SBO	83.18	83.15	74.43		88.45[b]
SBO FFA	76.81	77.81	71.08		71.21[a]

[1]Means followed by the same superscript are not significantly different ($P<0.05$), analysis was performed on transformed data.

[2]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.

[3]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[4]FFA indicates free fatty acids.

[5]Indicates Canola and Sunflower oil blended 5/5 (weight/weight).

significant ($P < 0.05$) increase in absorption (80.26% in the intact oil and 95.17% in the hydrolyzed oil). The concentration of this fatty acid is very low in the diet and oil however, so it may be assumed that this does not significantly alter the overall performance of the oil. The 5/5 blend behaved somewhat differently than either the Canola or sunflower oil. This blend had significantly ($P < 0.05$) depressed C18:2 and C18:3 absorption when hydrolyzed. The hydrolyzed blend showed depression in the absorption of all of the fatty acids except C24:0 (which increased but not significantly). This result closely resembled the soybean oil results which showed that hydrolysis of soybean oil reduced the absorption of all of the fatty acids and significantly ($P < 0.05$) reduced the absorption of the C18:1, C18:2, C18:3 and C24:0. These results agree with those published by Sklan (1979). But Renner and Hill (1961a) reported that the decrease in absorbability (due to hydrolysis) of the saturated fatty acids was much greater than that of the unsaturated fatty acids. This experiment did not show this trend. The reasons for the differences between the patterns of absorption of hydrolyzed sunflower and Canola oil versus the 5/5 blend and soybean oil are not clear. It is possible that the positional isomerism of the triglyceride of the soybean oil was responsible but there was no other evidence to support this. A better explanation may lie in the fatty acid profile of the oils. That is, the fatty acid profile of the blend most nearly matches that of the soybean oil and this may influence the absorption. The major drawback to this explaination comes from the other pair of

oils. The sunflower and Canola oils behave in very similar ways when hydrolyzed but there are very considerable differences in their fatty acid profiles.

In any case, it can be seen that feeding hydrolyzed oils in practical diets does not significantly affect chick performance or absorption of diet or fat except in the case of the soybean oil. It also appears that the individual fatty acid absorption was little affected by hydrolysis of the oil except in the cases of the blend and soybean oil. Therefore, it can be concluded that hydrolyzed oils may be useful in the study of lipid absorption, metabolism and fat soluble vitamin or steroid absorption as suggested by Chen (1979) and Hakkarainen et al (1983). However, more research is needed to explain the behavior of the hydrolyzed soybean oil and oil blend before these preparations can be used in the study of fatty acid balance.

PHYSICO-CHEMICAL ANALYSIS

Oil stability

Two tests (peroxide value and thiobarbituric acid test) were used to assess the autoxidative stability of the oils in the oven stability test. The results of the peroxide test indicate that the sunflower oil was relatively more oxidized than the Canola oil or the soybean oil (Table 14). The peroxide values of the Canola and soybean oil at day 0 were 2.05 and 5.22 milliequivalents/1000 gm of oil, respectively. This agrees with the values reported by Eskin and Frenkel (1977). The high value of 15.01 milliequivalents/1000 gm oil obtained for the sunflower oil and the straight line (Figure 1) of the plotted peroxide values over time indicates that this oil was already past its induction point. The data indicates that all of the anti-oxidants in the oil had been oxidized before the oven test was started. This would have had little impact on the feeding trials as Oertel and Hartfiel (1982) reported that poultry fed either fresh or oxidized oil (peroxide values of 90-180 milliequivalents/1000 gm oil) showed no differences in feed consumption, weight gain or feed efficiency. However this high peroxide value would have marked effects on the stability of the blended oils. Blending the Canola oil with the relatively oxidized sunflower oil would reduce the induction period of the Canola oil. Therefore, one would expect to see an increasing peroxide value at Day 0 and continuing through the period of the oven test with increasing amounts of sunflower oil in the blend. This trend is clearly shown in Figure 1. However, the peroxide

Table 14. Peroxide Values Under Accelerated Storage.

Oil	Peroxide Value[1]					
	Day 0	Day 2	Day 5	Day 8	Day 12	Day 16
CAO[2]	2.05±0.58	6.34±.591	16.63±0.16	30.15±1.92	44.72±0.39	61.20±0.37
SFO	15.01±0.10	28.62±0.25	45.84±0.72	64.59±0.49	89.13±1.88	120.68±0.58
5/5[3]	9.11±0.15	17.07±0.98	31.58±0.10	46.66±0.43	68.00±1.15	90.45±0.28
7/3	6.24±0.44	12.05±0.33	22.85±0.90	32.91±0.82	52.33±0.08	71.44±0.91
SBO	5.22±1.01	13.28±0.87	26.27±0.18	41.29±0.52	59.23±1.88	83.19±1.04

[1]Milli-equivalents per 1000 grams of oil (± standard deviation).

[2]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[3]Indicates Canola and sunflower oil blended 5/5 (weight/weight).

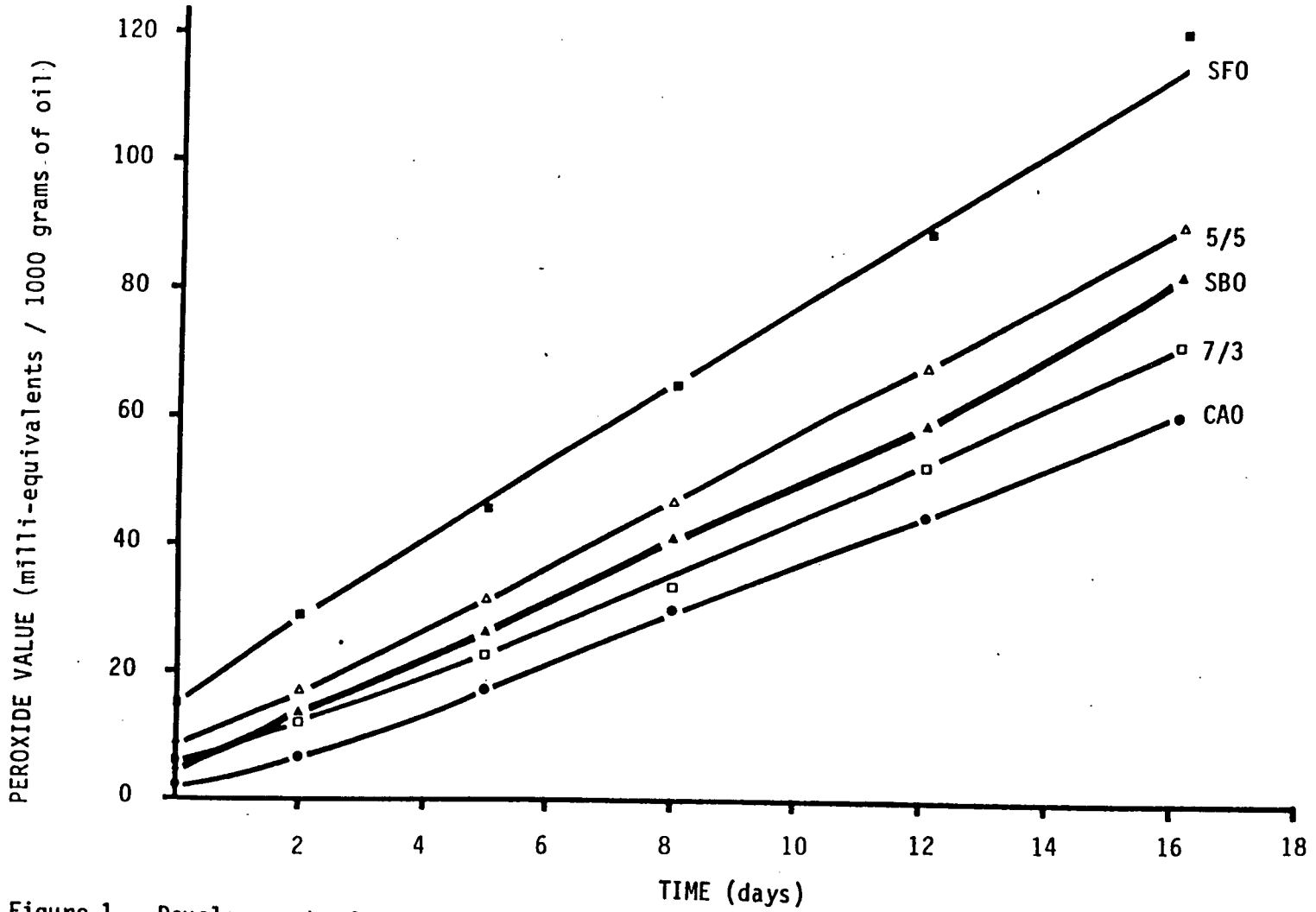

Figure 1. Developement of Peroxide values under accelerated storage conditions (70°C.).

value of the 2 blends tested were not dramatically different from the soybean oil over the test period. More importantly the peroxide values for the blends fell between those of the Canola oil and sunflower oil indicating there was not a synergistic decrease in stability due to the blending. The lack of synergism indicates that blending does not have a serious impact on the developement of peroxide value in an oil.

These results were substantiated by the thiobarbituric acid test. In contrast to the peroxide values the thiobarbituric acid values (absorbance at 530 nm) for the 3 oils and 2 blends were identical at the beginning of the deterioration test (Table 15). However, they showed substantial differences in the developement of thiobarbituric acid reactive substances during the test (Figure 2). It can be seen that the sunflower oil developed the thiobarbituric acid reactive substances more slowly and attained a total amount which was less than the other oils in spite of being more oxidized to begin with. This was probably due to the small amount of linolenic acid associated with this oil. The pattern of level of linolenic acid in the oil was Canola oil > soybean oil > 7/3 > 5/5 > sunflower oil and Table 15 shows that the absorbance at 16 days reflects this same pattern.

At 2 days of incubation the 7/3 and 5/5 blends showed a synergistic increase in absorbance. The increase was probably due to the oxidized state of the sunflower oil, as the degree of oxidation increased with the increase in amount of sunflower oil in the blend. Since sunflower oil alone did not develope this level of absorbance it may be assumed that the peroxides added to

Table 15. Thiobarbituric Acid Values Under Accelerated Storage.

Oil	2-Thiobarbituric Acid Value[1]				
	Day 0	Day 2	Day 5	Day 8	Day 16
CAO[2]	0.02±0.00	0.22±0.01	1.47±0.08	1.73±0.04	1.86±0.03
SFO	0.02±0.00	0.05±0.00	0.08±0.01	0.13±0.01	0.49±0.01
5/5[3]	0.02±0.00	0.37±0.01	0.74±0.03	0.92±0.00	0.99±0.04
7/3	0.02±0.00	0.28±0.00	0.84±0.06	1.10±0.01	1.21±0.01
SBO	0.02±0.00	0.68±0.01	1.15±0.01	1.31±0.01	1.20±0.01

[1]Absorbance at 530 nm (± standard deviation).

[2]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[3]Indicates Canola and sunflower oil blended 5/5 (weight/weight).

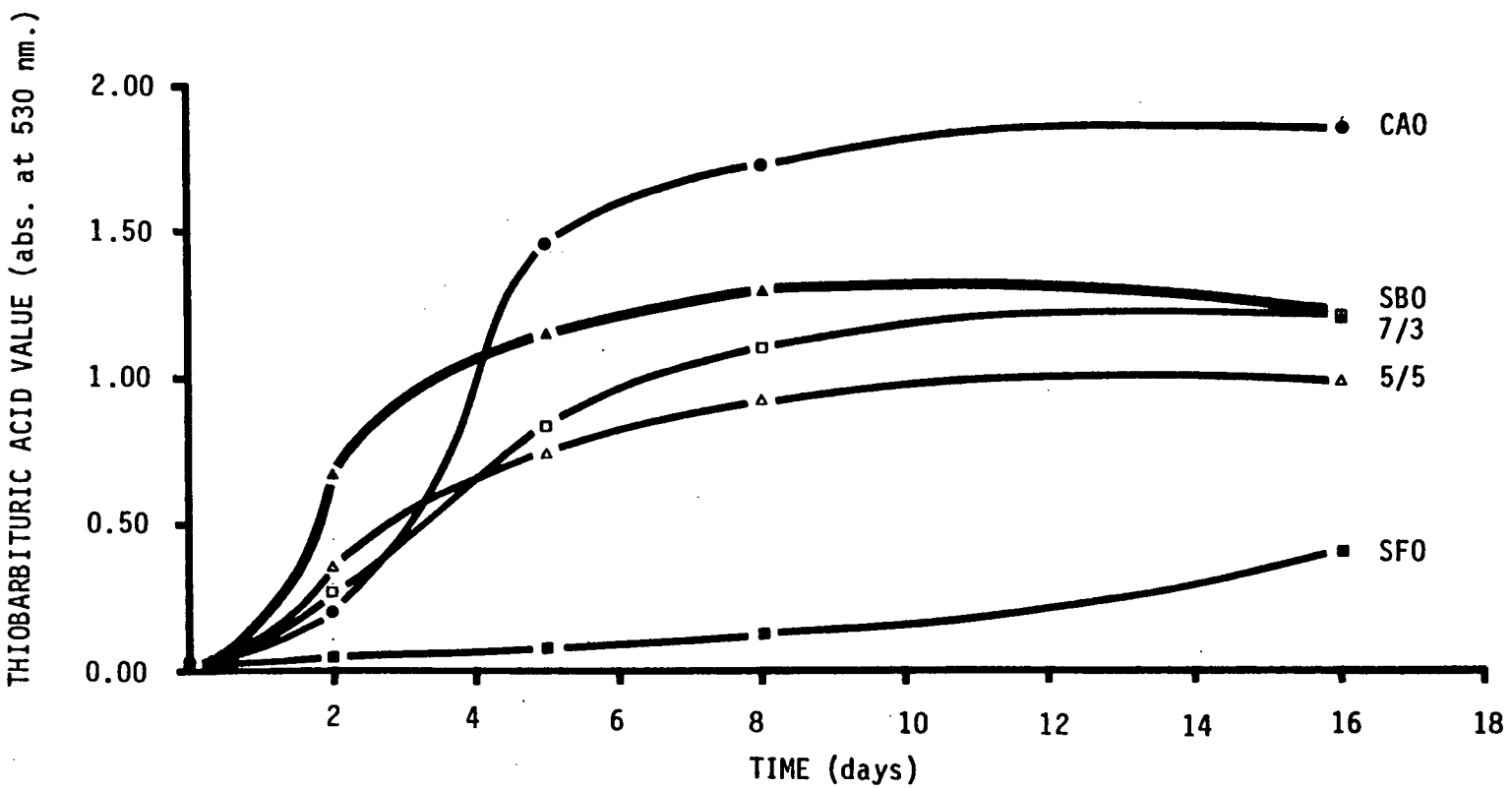

Figure 2. Developement of Thiobarbituric Acid value under accelerated storage (70°C.).

the blend by the sunflower oil hastened the deterioration of the linolenic acid in the blend. This hastened deterioration was also reflected in the reduced induction periods of the blends as shown in Figure 2. Despite this synergism the induction period of the blends was still greater than that shown by the soybean oil and the total absorbance attained in the blends was equivalent to or less than that of the soybean oil.

The absorbances at 16 days for the Canola and soybean oils were considerably higher than those reported by Eskin and Frenkel (1977), this probably reflects the differences in temperature at which the oven test was conducted and the hydrogenation of the soybean oil used by those researchers.

It was concluded that blending did not seriously alter the patterns of peroxide value or thiobarbituric acid value developement and, therefore, did not significantly reduce the oxidative stability of the oils involved.

Smoke points

Table 16 shows that all of the oils were well above the Canadian government standard of 200°C for frying oils. The values obtained for the Canbra, sunflower and soybean oils compare well with those published in Canadian Consumer (1977), although they are approximately 6°C higher than the reported values. It can be seen that the blending of sunflower and Canola oil in 5/5 and 7/3 proportions did not synergistically change the smoke points. This was to be expected as the smoke point is a measure of molecular weight and free fatty acid content of an oil. There was no evidence that blending alters these parameters.

Table 16. Oil Smoke Point.

Oil Type	Smoke Point[1] ± SD[2]
Canbra	244 ± 1.53
Canola	247 ± 1.15
Sunflower	252 ± 0.58
Soybean	246 ± 1.00
5/5[3]	249 ± 0.58
7/3	246 ± 0.58

[1]Degrees Celsius.

[2]Standard deviation (n = 3).

[3]Indicates Canola and Sunflower oil blended 5/5 (weight/weight).

SUMMARY AND CONCLUSIONS

The effects of balancing the fatty acid profiles of Canbra (6.1% erucic acid) and Canola (0.55% erucic acid) oils by blending with other fats or oils on chick performance and fatty acid absorption, as well as, the autoxidative stability and smoke point of the oil were investigated. In addition, the feasibility of feeding free fatty acids (hydrolyzed oils) to study the effects of fatty acid balancing was examined.

Canbra oil was blended with either sunflower oil or animal lard 1/1 (w/w). The Canola oil was blended with sunflower oil in the ratios 9/1, 8/2, 7/3, 6/4 and 5/5. The nutritional value of the oils was assayed using growing chicks fed lipid at 8% in a practical diet over a 4 week feeding period. The criteria used for evaluation were body weight, weight gain, feed consumption, feed conversion, feed digestibility, diet metabolizable energy, lipid digestibility, total fatty acid digestibility and individual fatty acid digestibility. The effects of dietary additions of Canbra oil, animal lard, sunflower oil, blends of Canbra oil with animal lard or sunflower oil, Canola oil, soybean oil, and blends of Canola oil and sunflower oil on chick performance and utilization were compared and discussed.

Under the conditions of this investigation it was observed that Canbra oil was equivalent to animal lard and significantly ($P < 0.05$) inferior to sunflower oil in the promotion of growth

and feed consumption. The blends of Canbra oil and animal lard or sunflower oil showed increased weight gain and consumption over the Canbra oil fed alone. In the case of the Canbra oil/animal lard blend this increase was synergistic. There were no differences in feed conversion, feed digestibility or total fatty acid digestibility between these treatments. Canbra oil was significantly ($P < 0.05$) inferior to the other treatments in lipid digestibility. This indicates that both blends exibited a synergistic increase in lipid digestibility. The individual fatty acids of the Canbra oil and animal lard generally were less absorbable than those of the sunflower oil. Blending Canbra oil with either animal lard or sunflower oil caused synergistic increases in the absorbability of the majority of the individual fatty acids.

Canola oil, sunflower oil and soybean oil were determined to be equivalent in the promotion of weight gain and feed consumption. All of the blends of Canola and sunflower oil except the 8/2 and 6/4 blends showed synergistic increases in body weight. The largest weight gain was demonstrated by the 7/3 blend and this was significantly ($P < 0.05$) greater than the weight gains promoted by either the sunflower oil or the soybean oil. The feed digestibility of the soybean oil treatment was significantly ($P < 0.05$) higher than that of the Canola oil or sunflower oil treatments. However, the synergism in feed digestibility shown by the 7/3, 6/4 and 5/5 blends raised this parameter to a level equivalent to the digestibility shown in the soybean oil treatment. This pattern was also shown in nitrogen

retention and apparent metabolizable energy of the diets with the 5/5 and 7/3 blends consistantly performing the best. There were no significant differences in the feed conversion or total fatty acid digestibility between any of these treatments. In terms of individual fatty acids those derived from Canola oil generally were less absorbable than those derived from the soybean oil. The 7/3 and 5/5 blends showed synergistic increases in the absorption of individual fatty acids to a level equivalent to or exceeding values obtained for the fatty acids of soybean oil. This was particularly true for the essential fatty acids.

The autoxidative stability of the oils and blends was assessed by determining peroxide values and thiobarbituric acid values over time in an oven test. Results showed that blending had no serious detrimental effects on oil stability. This was also true of the smoke points.

Several conclusions were drawn from these results. Fatty acid balancing of Canbra oil by blending with either animal lard (saturated fat) or sunflower oil (unsaturated oil) improves chick weight gain, feed consumption, lipid absorption and individual fatty acid absorption. Fatty acid balancing of Canola oil with sunflower oil improves chick weight gain, feed digestibility, nitrogen retention, individual fatty acid absorption, and therefore dietary apparent metabolizable energy compared to Canola oil or sunflower oil fed individually. This was most noticable for the 5/5 and 7/3 (w/w) blends. The high degree of correlation between weight gain and feed consumption shown in all cases indicates that in <u>ad libitum</u> feeding, feed consumption

is the most important factor in chick weight gain.

The feasibility of feeding hydrolyzed oils (free fatty acid mixtures) was assayed by feeding hydrolyzed Canola oil, sunflower oil, soybean oil and a 5/5 blend of Canola and sunflower oil or the corresponding intact oils at 8% of a practical diet. Criteria for evaluation of performance were the same as described previously.

Results showed that hydrolyzed Canola and sunflower oil were equivalent to the intact oils in nutritive performance. The hydrolyzed blend was equivalent to the intact blend in growth promotion, feed consumption, feed conversion and lipid absorption but showed significant ($P < 0.05$) reduction in the absorbability of some individual fatty acids. Hydrolyzed soybean oil while supporting the same growth in chicks showed a significantly ($P < 0.05$) reduced diet and fatty acid absorption. It was concluded that feeding hydrolyzed oils may be a useful tool in the study of fatty acid balance but that further research is needed to elucidate the reduced absorbability shown by the hydrolyzed blend and soybean oil.

BIBLIOGRAPHY

Abdellatif, A.M.M. and R.O. Vles, 1970. Pathological effects of dietary rapeseed oil in rats. Nutrition and Metabolism, 12:285-295.

Ackman, R.G., 1983. Chemical composition of rapeseed oil. In: High and Low Erucic Acid Rapeseed Oils. Production, Usage, Chemistry and Toxicological Evaluation. J.K.G. Kramer, F.D. Sauer and W.J. Pigden eds. Academic Press. New York, New York. Pp. 85-129.

Alexander, J.C. and F.H. Mattson, 1966. A nutritional comparison of rapeseed oil and soybean oil. Canadian Journal of Biochemistry. Vol 44: 35-43.

AOAC (Association of Official Analytical Chemists), 1980. Official methods of analysis, 13th ed. Section 28. Washington, D.C.

AOCS (Official and Tentative Methods of the American Oil Chemists' Society, 3rd ed.), 1980. R.O. Walker ed. American Oil Chemists' Society, Champaign, Illinois.

Artman, N.R., 1964. Interactions of fats and fatty acids as energy sources for the chick. Poultry Science 43:994-1004.

Atteh, J.O. and S. Leeson, 1983. Effects of dietary fatty acids and calcium levels on performance and mineral metabolism of broiler chickens. Poultry Science 62:2412-2419.

Austreng, E., A. Skrede and A. Eldegard, 1979. Effect of dietary fat source on the digestibility of fat and fatty acids in Rainbow Trout and Mink. Acta Agriculturae Scandinavica, 29:119-126.

Balnave, D., 1970. Essential fatty acids in poultry nutrition. World's Poultry Science Journal, 26:442-460.

Beare-Rogers, J.L., 1977. Docosenoic acids in dietary fats. In: Chemistry of Fats and Other Lipids. Vol 15, pp. 29-56. Pergamon Press, Great Britain.

Beare-Rogers, J.L., L. Gray, E.A. Nera and O.L. Levin, 1979. Nutritional properties of poppyseed oil relative to some other oils. Nutrition and Metabolism, 23:335-346.

Beare-Rogers, J.L., E.A. Nera and H.A. Heggtveit, 1971. Cardiac lipid changes in rats fed oils containing long-chain fatty acids. Canadian Institute of Food Technology Journal, 4:120-124.

Bellenand, J.F., G. Baloutch, N. Ong and J. Lelerf, 1980. Effects of coconut oil on heart lipids and on fatty acid utilization in rapeseed oil. Lipids, Vol 15, #11:938-943.

Biely, J. and B. March, 1954. Fat studies in poultry, 2. Fat supplements in chick and poult rations. Poultry Science 33: 1220-1227.

Biely, J. and B. March, 1957. Fat studies in poultry, 7. Fat and nitrogen retention in chicks fed diets containing different levels of fat and protein. Poultry Science 36:1235-1240.

Bieri, J.G., G.M. Briggs, M.R. Spivey-Fox, C.J. Pollard and L.O. Ortiz, 1956. Essential fatty acids in the chick, 1. Developement of fat-deficiency. Proceedings of the Society of Experimental Biology and Medicine, 93:237-240.

Borgstrom, B., 1977. Intestinal absorption of fats. Bibliotheca Nutrio et Dieta, 25:1-6.

Bragg, D.B., J.S. Sim, and G.C. Hodgson, 1973. Influence of dietary energy source on performance and fatty liver syndrome in White Leghorn laying hens. Poultry Science 52:736-740.

Burr, G.O. and M.M. Burr, 1929. A new deficiency disease produced by the rigid exclusion of fat from the diet. Journal of Biological Chemistry, 82:345-367.

Burr, G.O. and M.M. Burr, 1930. The nature and role of the fatty acids essential in nutrition. Journal of Biological Chemistry, 86:587-621.

Campbell, S.,1982. Report on the Canola Council of Canada technical seminar and mission to Algiers.

Canadian Consumer, 1977. Test: Cooking oils and fats. February, p. 45.

Carew, L.B. Jr., D.T. Hopkins and M.C. Nesheim, 1964. Influence of amount and type of fat on metabolic efficiency of energy utilization by the chick. Journal of Nutrition, 83:300-306.

Carroll, K.K., 1958. Digestibility of individual fatty acids in the rat. Journal of Nutrition, 64:399-410.

Carroll, K.K. and J.F. Richards, 1958. Factors affecting digestibility of fatty acids in the rat. Journal of Nutrition, 64:411-428.

Chen, S.C.-H., 1979. Feeding free fatty acids to study lipid metabolism in rats. Journal of Nutrition, 109:39-47.

Chow, S.L. and D. Hollander, 1979. Linoleic acid absorption in the unanesthetized rat: mechanism of transport and influence of luminal factors on absorption. Lipids, Vol 14, No. 4:378-385.

Clandinin, T., S.M. Innis and R. Renner, 1978. The effect of high and low erucic acid rapeseed oil on energy metabolism in chicks. Proceedings of the 5th International Rapeseed Conference, Malmo, Sweden. Vol 2:279-283.

Corino, C., V. Dell'Orto and O. Pedron, 1980. Effetti della composizione acidica di grassi ed olii sulla efficacia nutritiva dei mangimi per broilers. Revista Di Zootecnia E Veterinaria, No. 2:94-98.

Craig, B.M. and J.L. Beare, 1968. Nutritional properties of Canadian Canbra oil. Canadian Institute of Food Technology Journal, 1:64-67.

Crawford, M.A., P. Budowski, W. Hare and A.G. Hassam, 1982. A question of fatty acid essentiality. Journal of the American Oil Chemists' Society, 59:290A-291A.

Dale, N.M. and H.L. Fuller, 1982. True metabolizable energy of fats at low level dietary inclusion. Poultry Science 61:2415-2420.

Dam, R., R.M. Leach, Jr., T.S. Nelson, L.C. Norris and F.W. Hill, 1959. Studies on the effect of quantity and type of fat on chick growth. Journal of Nutrition, 68:615-632.

Daun, J.K., 1983. The introduction of low erucic acid rapeseed varieties into Canadian production. In: High and Low Erucic Acid Rapeseed Oils: Production, Usage, Chemistry and Toxicological Evaluation. J.K.G. Kramer, F.D. Sauer and W.J. Pigden eds. Academic Press, Toronto. Pp.161-180.

Donaldson, W.E., G.F. Combs, G.L. Romoser and W.C. Supplee, 1957. Studies on energy levels in poultry rations, 2. Tolerance of growing chicks to dietary fat. Poultry Science, 36:807-815.

Engfeldt, B. and E. Brunius, 1975. Morphological effects of rapeseed oil in rats, II. Long term studies. Acta Medica Scandinavica. Supplementa, Vol 585:27-40.

Eskin, N.A.M. and C. Frenkel, 1977. A study of the deterioration of soybean and rapeseed oils by measurement of hydroperoxides. Proceedings of the 13th World Congress International Society Fat Research. Pp. A1-7.

Farnworth, E.R. and J.K.G. Kramer, 1983. The effect of dietary fatty acids on the growth and carcass composition in the rat. Nutrition Reports International, 27:794-809.

Fedde, M.R., P.E. Waibel and R.E. Burger, 1960. Factors affecting the absorbability of certain dietary fats in the chick. Joournal of Nutrition, 70:447-452.

Folch, J., M. Lees and G.H. Sloane-Stanley, 1957. A simple method for the isolation and purification of total lipides from animal tissues. Journal of Biological Chemistry, 226:497-509.

Formo, M.W., 1979. Physical properties of fats and fatty acids. In: Bailey's Industrial Oil and Fat Products. Daniel Swern ed. John Wiley and Sons, New York, Chichester, Brisbane and Toronto. Pp.177-232.

Freeman, C.P., 1983. Fat supplementation in animal production-monogastric animals. Procedures of the Nutritional Society, 42:351-359.

Fulco, A.J. and J.F. Mead, 1959. Metabolism of essential fatty acids, VII. Origin of 5, 8, 11-eicosatrienoic acid in the fat-deficient rat. Journal of Biological Chemistry, 234:1411-1416.

Fuller, H.L. and N.M. Dale, 1982. Effect of ratio of basal diet fat to test fat on the true metabolizable energy of the test fat. Poultry Science, 61:914-918.

Griffiths, L., S. Leeson and J.D. Summers, 1977. Influence of energy system and level of various fat sources on performance and carcass composition of broilers. Poultry Science, 56:1018-1026.

Griminger, P., 1976. Lipid Metabolism. In: Avian Physiology, 3rd Edition. P.D. Sturkie ed. Springer-Verlag, New York, Heidelberg, Berlin. Pp. 252-262.

Guyton, A.C., 1976. Textbook of Medical Physiology. W.B. Saunders Company. Philadelphia, London, Toronto. Pp. 883-891.

Hakansson, J., 1974. Factors affecting the digestibility of fats and fatty acids in chicks and hens. Swedish Journal of Agricultural Research, 4:33-47.

Hakkarainen, J., S. Hassan, J. Tyopponen and P. Lindberg, 1983. Vitamin E deficient fat component for composing experimental diets. Acta Veterenaria Scandinavica, 24:129-132.

Hamilton, R.M.G. and B.E. McDonald, 1969. Effect of dietary fat source on the apparent digestibility of fat and the composition of fecal lipids of the young pig. Journal of Nutrition, 97:33-41.

Hendersen, E.W. and W.E. Irwin, 1940. The tolerence of growing chicks for soybean oil in their ration. Poultry Science, 19:389-395.

Hill, F.W. and D.L. Anderson, 1958. Comparison of metabolizable energy and productive energy determinations with growing chicks. Journal of Nutrition, 64:587-603.

Holman, R.T., 1960. The ratio of trienoic:tetraenoic acids in tissue lipids as a measure of essential fatty acid requirement. Journal of Nutrition, 70:405-410.

Holman, R.T., 1964. Nutritional and metabolic interrelationships between fatty acids. Federation Proceedings, 23:1062-1067.

Holman, R.T., 1975. Deficiency of essential fatty acids in humans. In: The Essential Fatty Acids. Miles Symposium, 1975. W.W. Hawkins ed. The Nutrition Society of Canada, University of Manitoba, Winnipeg. Pp. 45-57.

Holman, R.T., 1982. Linolenic acid as an essential fatty acid and its interaction with Linoleic acid. Journal of the American Oil Chemists Society, 59:290A.

Hopkins, C.Y., T.K. Murray and J.A. Campbell, 1955. Optimum ratio of saturated to mono-unsaturated fatty acids in rat diets. Canadian Journal of Biochemistry and Physiology, 33:1047-1054.

Hopkins, D.T., R.C. Witter and M.C. Neisheim, 1963. A respiratory disease syndrome in chickens fed essential fatty acid deficient diets. Proceedings of the Society of Experimental Biology and Medicine, 114:82-86.

Horani, F. and J.L. Sell, 1977. Effect of feed grade animal tallows on laying hen performance and on metabolizable energy of rations. Poultry Science, 56:1972-1980.

Houtsmuller, V.M.T, C.B. Struijk and A. Van Der Beek, 1970. Decrease in rate of ATP synthesis of isolated rat heart mitochondria induced by dietary erucic acid. Biochimica Biophysica Acta, 218:564-566.

Hulan, H.W., A.H. Corner, D.M. Nash and F.G. Proudfoot, 1982. Growth, heart weight, cardiac lipid, and pathology of chickens fed soybean oil, or oil extracted from different rapeseed cultivars. Poultry Science, 61:1154-1166.

Hulan, H.W., J.K.G. Kramer and A.H. Corner, 1977. Myocardial lesions in rats fed rapeseed oil, I. Influence of strain of rats. Canadian Journal of Physiological Pharmacology, 55:258-264.

Hulan, H.W., F.G. Proudfoot and D.M. Nash, 1984. The effects of different dietary fat sources on general performance and carcass fatty acid composition of broiler chickens. Poultry Science, 63:324-332.

Joshi, S.K. and J.L. Sell, 1964. Comparative dietary value of soybean oil, sunflower oil, rapeseed oil, and animal tallow for turkey poults. Canadian Journal of Animal Science, 44:34-38.

Katongole, J.B.D. and B.E. March, 1979. Fatty acid binding protein in the intestine of the chicken. Poultry Science, 58:372-375.

Katongole, J.B.D. and B.E. March, 1980. Fat utilization in relation to intestinal fatty acid binding protein and bile salts in chicks of different ages and different genetic sources. Poultry Science, 59:819-827.

Klenk, E. and H. Mohrhauer, 1960. Metabolism of polyene fatty acids in the rat. Journal of Physiology and Chemistry, 320:218-232.

Kramer, J.K.G., E.R. Farnworth, B.K. Thompson and A.H. Corner, 1981. The effect of dietary fatty acids on the incidence of cardiac lesions and changes in the cardiac phospholipids in male rats. Progress in Lipid Research, 20:491-499.

Kramer, J.K.G., H.W. Hulan, A.H. Corner, B.K. Thompson, N. Holfeld and J.H.L. Mills, 1979. Cardiopathogenicity of Soybean oil and Tower rapeseed oil triglycerides when fed to male rats. Lipids, 14:773-780.

Kramer, J.K.G., H.W. Hulan, S. Madahevan, F.D. Sauer and A.H. Corner, 1977. Nutritional evaluation of rapeseed oil-a review. In: Rapeseed Oil, Meal and By-product Utilization Proceedings, Vancouver, B.C. J.M. Bell, ed. Pp. 64-74.

Kramer, J.K.G., S. Madahevan, J.R. Hunt, F.D. Sauer, A.H. Corner and K.M. Charlton, 1973. Growth rate, lipid composition, metabolism and myocardial lesions of rats fed rapeseed oils (Brassica campestris var. Arlo, Echo and Span, and B. napus var. Oro). Journal of Nutrition, 103:1696-1708.

Kramer, J.K.G. and F.D. Sauer, 1983. Results obtained with feeding low erucic acid rapeseed oils and other vegetable oils to rats and other species. In: High and Low Erucic Acid Rapeseed Oils. Production, Usage, Chemistry, and Toxicological Evaluation. J.K.G. Kramer, F.D. Sauer, and W.J. Pigden eds. Academic Press, New York, New York. Pp. 414-474.

Kussaibati, R., J. Guillaume and B. Leclercq, 1982. The effects of endogenous energy, type of diet, and addition of bile salts on true metabolizable energy values in young chicks. Poultry Science, 61:2218-2223.

Lall, S.P. and S.J. Slinger, 1973. The metabolizable energy content of rapeseed oils and rapeseed oil foots and the effect of blending with other fats. Poultry Science, 52:143-151.

Lands, W.E.M., 1975. Selectivity of microsomal acyltransformases. Miles Symposium, 1975. W.W. Hawkins ed. The Nutrition Society of Canada, University of Manitoba, Winnipeg. Pp. 15-26.

Leeson, S. and J.D. Summers, 1976. Fat M.E. Values: The Effect of fatty acid saturation. Feedstuffs, 48:26-28.

Lewis, D. and C.G. Payne, 1966. Fats and amino acids in broiler rations, 6. Synergistic relationships in fatty acid utilization. British Poultry Science, 66:209-218.

Machlin, L.J., 1962. Effect of dietary linolenate on the proportion of linoleate and arachidonate in liver. Nature, 194:868-869.

Machlin, L.J. and R.S. Gordon, 1960. The requirement of the chicken for certain unsaturated fatty acids (abstr.). Poultry Science, 39:1271.

March, B.E., 1977. Response of chicks to the feeding of different rapeseed oils and rapeseed oil fractions. Canadian Journal of Animal Science, 57:137-140.

Mateos, G.G. and J.L. Sell, 1981. Nature of the extrametabolic effect of supplemental fat used in semi-purified diets for laying hens. Poultry Science, 60:1925-1930.

Mead, J.F., 1961. Synthesis and metabolism of polyunsaturated acids. Federation Proceedings, 20:952-955.

Menge, H. and C.A. Denton, 1961. Effect of dried egg yolk, oils and fat on chick growth. Journal of Nutrition, 75:107-115.

Mohrhauer, H. and R.T. Holman, 1963. Effect of linolenic acid upon the metabolism of linoleic acid. Journal of Nutrition, 81:67-74.

Morely, N.H., A. Kuksis and D. Buchnea, 1974. Hydrolysis of synthetic triacyl-glycerols by pancreatic and lipoprotein lipase. Lipids, 9:481-488.

Murphy, R.C., S. Hammerstrom and B. Samuelsson, 1979. Leukotriene C. A slow-reacting substance from murine mastocytoma cells. Proceedings of the National Academy of Sciences, U.S.A., 76:4275-4279.

Muztar, A.J., S. Leeson and S.J. Slinger, 1981. Effect of blending and level of inclusion on the metabolizable energy of tallow and Tower rapeseed soapstocks. Poultry Science, 60:365-372.

Needleman, P., A. Raz, M.S. Minkes, J.A. Ferrendelli and H. Sprecher, 1979. Triene prostaglandins: Prostacyclin and thromboxane biosynthesis and unique biological properties. Proceedings of the National Academy of Sciences, U.S.A., 76:944-948.

Nunn, L.C.A. and I. Smedley-Maclean, 1938. The nature of the fatty acids stored by the liver in the fat-deficiency disease of rats. The Biochemical Journal, 32:2178-2184.

Ockner, R.K., J.A. Manning, R.B. Poppenhausen and W.K.L. Ho, 1972. A binding protein for fatty acids in cytosol of intestinal mucosa, liver, myocardium and other tissues. Science, 177:56-58.

Oertel, V.M.L. and W. Hartfiel, 1982. Effect of fresh and oxidized fats/oils and of pro- and antioxidants on the growth of broiler chicks. Archiv Fur Geflugelkunde 1:13-17.

Rand, N.T., H.M. Scott and F.A. Kummerow, 1958. Dietary fat in the nutrition of the growing chick. Poultry Science, 37:1075-1085.

Reiser, R., 1950. The essential role of fatty acids in rations for growing chicks. Journal of Nutrition, 42:319-323.

Renner, R. and F.W. Hill, 1960. The utilization of corn oil, lard and tallow by chickens of various ages. Poultry Science, 39:849-854.

Renner, R. and F.W. Hill, 1961a. Factors affecting the absorbability of saturated fatty acids in the chick. Journal of Nutrition, 74:254-258.

Renner, R. and F.W. Hill, 1961b. Utilization of fatty acids by the chicken. Journal of Nutrition, 74:259-264.

Rocquelin, G. and R. Cluzan, 1968. L'huile de Colza riche en acide erucique et L'huile de Colza sans acide erucique: valleur nutritionelle et effets physiologiques chez le rat, I. Effets sur la croissance, l'efficacite alimentaire et l'etat de differents organes. Annales de Biologie Animale, Biochemie, Biophysique, 8:395-406.

Rocquelin, G. and J. Leclerc, 1969. L'huile de colza riche en acide erucique et l'huile de colza sans acide erucique. Annales de Biologie Animale, Biochemie, Biophysique, 9:413-426

Salmon, R.E., 1969a. Soybean versus rapeseed oil in turkey starter diets. Poultry Science, 48:87-93.

Salmon, R.E., 1969b. The relative values of rapeseed and soybean oils in chick starter diets. Poultry Science, 48:1045-1050.

Salmon, R.E., 1970. Rapeseed oil in poultry diets. Proceedings of the International Conference on the Science, Technology and Marketing of Rapeseed and Rapeseed Products. Ste. Adele, Quebec, Canada. Published by the Rapeseed Assoc. of Canada. Pp. 369-376.

Salmon, R.E., 1977. Effects of age on the absorption of fat by turkeys fed mixtures of beef fat and rapeseed oil. Canadian Journal of Animal Science, 57:427-431.

Sauer, F.D. and J.K.G. Kramer, 1983. The problems associated with the feeding of high erucic acid RSO and some fish oils to experimental animals. In: High and Low Erucic Acid Rapeseed Oils. Production, Usage, Chemistry and Toxicological Evaluation. J.K.G. Kramer, F.D. Sauer and W.J. Pigden eds. Academic Press, New York, New York. Pp. 254-292.

Savary, P. and M.J. Constantin, 1966. Sur la resorption intestinale des chaines eruciques et lear incorporation dans les chylomicrons lymphatiques du rat. Biochimica Biophysica Acta, 125:118-128.

Scott, M.L., M.C. Nesheim and R.J. Young, 1982. Nutrition of the Chicken, 3rd ed. M.L. Scott and Associates, Ithaca, New York. Pp. 562.

Scott, H.M., L.C. Sims and D.L. Staheli, 1955. The effect of varying protein and energy on performance of chicks (abstr.). Poultry Science, 34:1220.

Sell, J.L. and G.C. Hodgson, 1962. Comparative value of dietary rapeseed oil, sunflower seed oil, soybean oil and animal tallow for chickens. Journal of Nutrition, 76:113-118.

Sheppard, A.J., J.C. Fritz, W.H. Hooper, T. Roberts, W.D. Hubbard, A.R. Prosser and J.W. Boehne, 1971. Crambe and rapeseed oils as energy sources for rats and chicks and some ancillary data on organ weights and body cavity fat composition. Poultry Science 50:79-84.

Sibbald, I.R., 1979. Metabolizable energy evaluation of poultry chicks. In: Recent Advances in Animal Nutrition. W. Haresign and D. Lewis eds. Butterworths London. Pp.35-49.

Sibbald, I.R. and J.K.G. Kramer, 1977. The true metabolizable energy values of fats and fat mixtures. Poultry Science, 56:2079-2086.

Sibbald, I.R. and S.J. Slinger, 1960. A synergistic relationship between tallow and undegummed soybean oil (abstr.). Poultry Science, 39:1295.

Sibbald, I.R., S.J. Slinger and G.C. Ashton, 1961. Factors affecting the metabolizable energy content of poultry feeds, I. Variability in the M.E. values attributed to samples of tallow and undegummed soybean oil. Poultry Science, 40:303-308.

Sibbald, I.R., S.J. Slinger and G.C. Ashton, 1962. The utilization of a number of fats fatty materials, and mixtures thereof evaluated in terms of metabolizable energy, chick weight gains and gain:feed ratios. Poultry Science, 41:46-61.

Sidwell, C.G., H. Salwin, M. Benca and J.H. Mitchell, Jr., 1954. The use of thiobarbituric acid as a measure of fat oxidation. Journal of the American Oil Chemist's Society, 31:603-606.

Sklan, D., 1979. Digestion and absorption of lipids in chicks fed triglycerides or free fatty acids: Synthesis of monoglycerides in the intestine. Poultry Science, 58:885-889.

Slinger, S.J., 1977. Rapeseed, rapeseed oil and refining by-products in feeds. In: Rapeseed Oil, Meal and By-Product Utilization Proceedings, Vancouver, B.C. J.M. Bell ed. Pp. 93-111.

Sonntag, N.O.V., 1979. Reactions of fats and fatty acids. In: Bailey's Industrial Oil and Fat Products. Daniel Swern ed. John Wiley and Sons, New York, Chichester, Brisbane and Toronto. Pp. 99-175.

Sprecher, H., 1975. Biosynthesis of polyunsaturated fatty acids. Miles Symposium, 1975. W.W. Hawkins ed. The Nutrition Society of Canada. University of Manitoba, Winnipeg.

Sprecher, H., 1981. The regulation of unsaturated fatty acid biosynthesis. In: New Trends in Nutrition, Lipid Research and Cardiovascular Diseases. Bazan and Paoletti eds. A.R. Liss, Inc., New York, New York. Pp. 3-15.

Sprecher, H., 1983. The mechanisms of fatty acid chain elongation and desaturation in animals. In: High and Low Erucic Acid Rapeseed Oils. Production, Usage, Chemistry and Toxicological Evaluation. J.K.G. Kramer, F.D. Sauer and W.J. Pigden eds. Academic Press, New York, New York. Pp. 385-411.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics. A Biometrical Approach, 2nd ed. McGraw-hill Book Company, New York. Pp. 633.

Steinberg, G., W.H. Slaton, D.R. Howton and J.F. Mead, 1956. Metabolism of essential fatty acids, IV. Incorporation of linoleate into arachidonic acid. Journal of Biological Chemistry, 220:257-264.

Steinberg, G., W.H. Slaton, D.R. Howton and J.F. Mead, 1957. Metabolism of essential fatty acids, V. Metabolic pathway of linolenic acid. Journal of Biological Chemistry, 224:841-849.

Swiss, L.D. and H.S. Bayley, 1976. Influence of the degree of hydrolysis of beef tallow on its absorption in the young pig. Canadian Journal of Pharmacology, 54:719-727.

Tinoco, J., R. Babcock, I. Hinlenbergs, B. Medwadowski, P. Miljanich and M.A. Williams, 1979. Linolenic acid deficiency. Lipids, 14:167-173.

Vergroesen, A.J., E.A.M. DeDeckere, F. Ten Hoor, G. Hornstra and U.M.T. Houtsmuller, 1975. Physiological functions of the essential fatty acids. Miles Symposium, 1975. W.W. Hawkins ed. The Nutrition Society of Canada, University of Manitoba Winnipeg. Pp. 5-12.

Vermeersch, G. and F. Vanschoubroek, 1968. The quantification of the effect of increasing levels of various fats on body weight gain, efficiency of food conversion and food intake of growing chicks. British Poultry Science, 9:13-30.

Vles, R.O., G.M. Bijster and W.G. Timmer, 1977. Nutritional evaluation of low erucic acid rapeseed oils. Archives of Toxicology Supplement, 1:23-32.

Waibel, P.E., 1955. Effect of dietary protein level and added tallow on growth and carcass composition of chicks (abstr.) Poultry Science, 34:1226.

Waibel, P.E., 1958. Effectiveness of unknown growth factors, antibiotics and animal fat in turkey poultry rations. Poultry Science, 37:1144-1149.

Walker, B.L., S.P. Lall, S.J. Slinger and H.S. Bayley, 1970. Nutritional aspects of rapeseed oil: digestibility, processing and influence of erucic acid on tissue lipids. Proceedings of the International Conference on the Science, Technology and Marketing of Rapeseed and Rapeseed Products. Ste. Adele, Quebec, Canada. Pp. 377-404.

Ward, T.A. and R.R. Marquardt, 1983. The effect of saturation, chain length of pure triglycerides, and age of bird on the utilization of rye diets. Poultry Science, 62:1054-1062.

Whitehead, C.C. and C. Fisher, 1975. The utilization of various fats by turkeys of different ages. British Poultry Science, 16:481-485.

Widmer, C., Jr. and R.T. Holman, 1950. Polythenoid fatty acid metabolism, II. Deposition of polyunsaturated fatty acids in fat-deficient rats upon single fatty acid supplementation. Arch. Biochem., 25:1-12.

Yacowitz, H., 1953. Supplementation of corn-soybean oil meal rations with penicillin and various fats (abstr.). Poultry Science, 32:930.

Young, R.J., 1961. The energy value of fats and fatty acids for chicks, I. Metabolizable energy. Poultry Science, 40:1225-1233.

Young, R.J. and N.R. Artman, 1961. The energy value of fats and fatty acids for chicks, II. Evaluated by controlled feed intake. Poultry Science, 40:1653-1662.

Young, R.J. and R.L. Garrett, 1963. Effect of oleic and linoleic acids on the absorption of saturated fatty acids in the chick. Journal of Nutrition, 81:321-329.

Young, R.J., R.L. Garrett and M. Griffith, 1963. Factors affecting the absorbability of fatty acid mixtures high in saturated fatty acids. Poultry Science, 42:1146-1154.

Ziemlanski, S., 1977. Pathophysiological effects of long-chain fatty acids. Bibliotheca Nutrio et Dieta, 25:134-157.

APPENDIX

TRIAL 4

Methods and materials

This experiment was designed to check the poor performance of the 8/2 blend of Canola and sunflower oil used in Trial 2 and to directly compare the Canbra and Canola oil.

Five experimental diets were formulated to incorporate either Canbra oil (6.1% erucic acid), Canola oil (0.55% erucic acid), sunflower oil or blends of Canola and sunflower oil at the ratios 8/2 and 7/3 (w/w) into a basal diet (Table 3). Experimental diets assigned at random in triplicate to 15 chick groups over a 4 week feeding period as described in Trials 1 and 2.

In this experiment only body weight, weight gain, feed consumption and feed conversion were measured. Prior to statistical analysis the data was combined with that of the corresponding treatments in Trials 1 and 2, this resulted in 6 replicates per treatment and an increase in statistical precision.

Results and discussion

It can be seen that Canola oil is significantly ($P < 0.05$) superior to both Canbra oil and sunflower oil in promoting weight gain (Table I). The data also shows that there is a marked increase in the final body weight and weight gain of the 8/2 blend over those reported in Trial 2. There is no significant difference between the 8/2 blend and the Canola oil in promotion of weight gain. The 7/3 blend is superior to the other treatments in this respect, although it is not significantly

Table I. Effect of Oil Blending on the Growth Performance of Chicks at 4 Weeks, Trial 4.

Dietary Oil	Chick Performance[1]			
	Body weight (g/bird)	Weight gain (g/bird)	Feed Consumed (g/bird)	Feed Conversion (g consumed/gain)
CAO[2]	331.6^{c-d}	293.9^{b}	598.0^{b-c}	2.04
8/2[3]	319.0^{b-c}	281.4^{a-b}	577.8^{a-b-c}	2.05
7/3	335.0^{d}	297.6^{b}	608.7^{c}	2.05
SFO	311.7^{a-b}	274.2^{a}	573.6^{a-b}	2.10
CBO	302.0^{a}	265.9^{a}	554.0^{a}	2.08
SEM[4]	5.16	5.28	10.83	0.03

[1]Means not followed by the same superscript are significantly different ($P < 0.05$).

[2]CAO = Canola oil, SFO = Sunflower oil, CBO = Canbra oil1

[3]Indicates Canola and Sunflower oil blended 8/2 (weight/weight).

[4]Standard error of the mean (n =3).

superior to the Canola oil. However it shows a definite trend in this direction which supports the results of Trial 2. It can be concluded that the 7/3 blend shows a positive synergistic increase in weight gain.

Table I also shows that the same pattern can be observed in total feed consumption. The consumption of feed was significantly ($P < 0.05$) greater in the Canola oil treatment than in the Canbra oil treatment. Even though the sunflower oil treatment showed less consumption than the Canola oil treatment this difference was not significant. The 7/3 blend treatment showed a trend toward higher consumption than the Canola oil confirming the results of Trial 2. In this experiment the correlation between weight gain and feed consumption was higher than that shown in Trials 1 and 2 ($r=0.99$). This indicates that in ad libitum feeding consumption is affected by blending oil and that this is a major factor in the weight gain of the chicks.

As in Trials 1 and 2 feed conversion was not significantly different between treatments.

Table II. Fatty Acid Composition of Diets, Trial 1.

Dietary Oil	Fatty Acid Content (per cent by weight)					
	C14:0[1]	C16:0	C16:1	C18:0	C18:1	C18:2
CBO[2]		5.51		1.96	49.69	25.80
SFO		7.94		5.21	18.71	63.37
AL	0.86	21.29	2.22	14.36	40.74	15.40
CBO+SFO[3]		6.71		3.69	35.94	45.51
CBO+AL	0.45	13.63	1.23	8.50	44.35	20.45

	C18:3	C20:0	C20:1	C22:0	C22:1	C24:0
CBO	8.38	0.72	3.37		4.56	
SFO	1.52	0.46	0.74	1.18	0.50	0.38
AL	1.85	0.34	1.33		0.31	
CBO+SFO	5.22	0.65	2.11	0.77	2.55	0.31
CBO+AL	5.05	0.52	2.24	0.22	2.24	

[1]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.

[2]CBO = Canbra oil, SFO = Sunflower oil, AL = Animal lard.

[3]Indicates oil blended 1:1 by weight.

Table III. Fatty Acid Composition of Diets, Trial 2.

Dietary Oil	Fatty Acid Content (per cent by weight)					
	C14:0[1]	C16:0	C16:1	C18:0	C18:1	C18:2
CAO[2]		6.97	0.17	2.38	51.38	27.23
9/1[3]		7.06	0.16	2.63	47.79	31.39
8/2	0.12	7.38	0.15	2.90	44.44	34.69
7/3	0.21	7.39	0.14	3.19	41.01	38.53
6/4		7.06	0.13	3.34	37.89	42.78
5/5		7.66	0.11	3.74	33.99	46.59
SFO		8.57		5.13	16.77	66.52
SBO		11.53	0.11	4.26	23.37	51.29

	C18:3	C20:0	C20:1	C22:0	C22:1	C24:0
CAO	7.61	1.08	2.09	0.44	0.38	0.26
9/1	7.02	0.90	1.97	0.50	0.37	0.21
8/2	6.39	1.02	1.83	0.54	0.34	0.20
7/3	5.73	1.00	1.69	0.61	0.33	0.19
6/4	5.26	0.96	1.50	0.66	0.28	0.15
5/5	4.63	0.89	1.35	0.66	0.24	0.13
SFO	0.93	0.33	0.33	0.97	0.17	0.29
SBO	7.23	0.79	0.73	0.49		0.20

[1]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.

[2]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.

[3]Indicates Canola and Sunflower oil blended 9/1 (weight/weight).

Table IV. Fatty Acid Composition of Diets, Trial 3.

Dietary Oil	Fatty Acid Content (per cent by weight)					
	C14:0[1]	C16:0	C16:1	C18:0	C18:1	C18:2
CAO[2]		6.97	0.17	2.38	51.38	27.23
CAO FFA[3]		6.42	0.16	2.51	52.88	25.94
SFO		8.57		5.13	16.77	66.52
SFO FFA		8.37		5.79	17.11	65.36
5/5[4]		7.66	0.11	3.74	33.99	46.59
5/5 FFA		7.40	0.10	4.01	35.01	45.40
SBO		11.53	0.11	4.26	23.37	51.29
SBO FFA		11.75	0.09	4.65	23.75	50.13

	C18:3	C20:0	C20:1	C22:0	C22:1	C24:0
CAO	7.61	1.08	2.09	0.44	0.38	0.26
CAO FFA	7.10	1.21	2.38	0.60	0.49	0.33
SFO	0.93	0.33	0.33	0.97	0.17	0.29
SFO FFA	0.81	0.39	0.36	1.25	0.19	0.37
5/5	4.63	0.89	1.35	0.66	0.24	0.13
5/5 FFA	4.30	0.98	1.45	0.87	0.30	0.17
SBO	7.23	0.79	0.73	0.49		0.20
SBO FFA	7.08	0.84	0.76	0.60	0.13	0.23

[1]The number preceeding the colon indicates the length of the carbon chain, the number following indicates the number of double bonds present.
[2]CAO = Canola oil, SFO = Sunflower oil, SBO = Soybean oil.
[3]FFA indicates free fatty acids.
[4]Indicates Canola and Sunflower oil blended 5/5 (weight/weight).

Table V. Analysis of variance of growth parameters, Trial 1.

Parameter	Treatment df	Error df	Treatment MS	Error MS	F[1]
Body weight	4	10	285.79	54.06	5.29*
Weight gain	4	10	291.12	51.63	5.64**
Feed consumption	4	10	986.11	223.16	4.42*
Feed conversion	4	10	0.0037	0.0019	1.92

[1]Level of significance * = 5%, ** = 1%.

Table VI. Analysis of variance of digestibility coefficients, Trial 1.

Parameter	Treatment df	Error df	Treatment MS	Error MS	F[1]
Feed	4	10	1.36	0.91	1.50
Lipid	4	10	3.48	0.44	7.87**
Total fatty acid	4	10	4.52	2.11	2.14

[1]Level of significance * = 5%, ** = 1%, data was treated with arcsine transformation prior to analysis.

Table VII. Analysis of variance of individual fatty acid absorption, Trial 1.

Fatty acid	Treatment df	Error df	Treatment MS	Error MS	F[1]
C16:0	4	10	39.61	2.28	17.38**
C18:0	4	10	75.31	6.71	11.22**
C18:1	4	10	9.89	1.78	5.54*
C18:2	4	10	29.84	1.55	19.22**
C18:3	4	10	131.39	1.63	80.65**
C20:1	4	10	43.47	6.06	7.18*
C22:1	2	6	31.12	10.22	3.05

[1]Level of significance * = 5%, ** = 1%, data was treated with arcsine transformation prior to analysis.

Table VIII. Analysis of variance for growth parameters and AMEn, Trial 2.

Parameter	Treatment df	Error df	Treatment MS	Error MS	F[1]
Body weight	7	16	495.05	159.39	3.11*
Weight gain	7	16	496.15	155.85	3.18*
Feed consumption	7	16	1490.01	875.60	1.70
Feed conversion	7	16	0.0043	0.0023	1.87
AMEn	7	16	24577.30	7781.61	3.16*

[1]Level of significance * = 5%, ** = 1%.

Table IX. Analysis of variance of digestibility coefficients, Trial 2.

Parameter	Treatment df	Error df	Treatment MS	Error MS	F[1]
Feed	7	16	6.78	2.48	2.74*
Lipid	7	16	16.73	3.66	4.57**
Total fatty acid	7	16	15.09	8.43	1.79
Nitrogen retention	7	16	16.33	3.18	2.64*

[1]Level of significance * = 5%, ** = 1%, data was treated with arcsine transformation prior to analysis.

Table X. Analysis of variance of individual fatty acid absorption, Trial 2.

Fatty acid	Treatment df	Error df	Treatment MS	Error MS	F[1]
C16:0	7	16	14.71	3.81	3.86*
C18:0	7	16	18.96	10.22	1.85
C18:1	7	16	7.35	2.73	2.70
C18:2	7	16	12.16	1.97	6.18**
C18:3	7	16	35.29	1.61	21.87**
C20:0	7	16	19.12	9.85	1.94
C20:1	7	16	16.99	5.70	2.98*
C22:0	7	16	33.69	21.97	1.53
C22:1	6	14	29.80	14.93	2.00
C24:0	7	16	55.41	11.53	4.81**

[1]Level of significance * = 5%, ** = 1%, data was treated with arcsine transformation prior to analysis.

Table XI. Analysis of variance of growth parameters, Trial 3.

Parameter	Treatment df	Error df	Treatment MS	Error MS	F[1]
Body weight	7	16	297.50	248.23	1.20
Weight gain	7	16	279.85	242.86	1.15
Feed consumption	7	16	1562.10	1829.77	0.85
Feed conversion	7	16	0.0050	0.0027	1.84

[1]Level of significance * = 5%, ** = 1%.

Table XII. Analysis of variance of digestibility coefficients, Trial 3.

Parameter	Treatment df	Error df	Treatment MS	Error MS	F[1]
Feed	7	16	4.38	1.32	3.33*
Lipid	7	16	11.09	3.47	3.20*
Total fatty acid	7	16	9.61	3.833	2.51

[1]Level of significance * = 5%, ** = 1%, data was treated with arcsine transformation prior to analysis.

Table XIII. Analysis of variance of individual fatty acid absorption, Trial 3.

Fatty acid	Treatment df	Error df	Treatment MS	Error MS	F[1]
C16:0	7	16	10.87	5.16	2.10
C18:0	7	16	21.70	10.43	2.08
C18:1	7	16	15.59	3.43	4.54**
C18:2	7	16	17.22	2.21	7.81**
C18:3	7	16	37.66	2.21	17.02**
C20:0	7	16	11.82	10.66	1.11
C20:1	7	16	17.10	7.50	2.28
C22:0	7	16	32.05	20.78	1.54
C22:1	5	12	24.40	12.60	1.94
C24:0	7	16	184.14	35.79	5.15**

[1]Level of significance * = 5%, ** = 1%, data was treated with arcsine transformation prior to analysis.

Table . Analysis of variance for growth parameters, Trial 4.

Parameter	Treatment df	Error df	Treatment MS	Error MS	F[1]
Body weight	4	25	1131.34	159.49	7.09**
Weight gain	4	25	1055.73	167.58	6.30**
Feed consumption	4	25	2761.31	704.18	3.92*
Feed conversion	4	25	0.0040	0.0018	2.27

[1]Level of significance *≤5%, **≤1%.