EFFECT OF DIETARY FAT SOURCE ON ENERGY METABOLISM AT REST AND UNDER PHYSICAL WORK

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A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ABSTRACT

The comparative effect of canbra oil (from B. Napus cv Zephyr, 0.4% erucic acid) and soybean oil on energy metabolism at rest and under physical work was investigated in 4 young healthy college males. The metabolic study consisted of 3 experimental periods: A 10-day stabilization period during which a mixed fat diet was fed, and two 11-day experimental periods. During experimental period I two subjects received the soybean oil diet and two received the canbra oil diet. In experimental period II the diets were switched. Fat provided approximately 38% of the calories in the stabilization and experimental diets. The exercise protocol consisted of 3 phases: a 20 minute rest (Re) period, a 10 minute exercise (Ex) period and a 20 minute recovery (Rec) period. Each subject was exercised at 950 kilopond meters min. (approx. 66% maximum work capacity) on a bicycle ergometer, 2.5 hours after a test meal containing 68 grams of test fat. Respiratory exchange measurements and blood samples were taken during the Re-Ex-Rec periods after 8 days on the stabilization diet and on the first and tenth day of each experimental period. Respiratory exchange also was monitored in the resting state following an overnight fast at the end of experimental periods I and II. Respiratory gases were analysed for O_2 and Co_2 by the Sholander method. Blood samples were analysed for glucose, glycerol, lactate and pyruvate. In addition fasting

blood samples were taken on the first day of the study and at the end of each experimental period for the determination of whole blood hematology and serum lipid patterns. The subjects remained in good health throughout the study. Body weights remained constant and no dietary upsets were reported. Respiratory quotients (RQ) on the mixed fat, soybean and canbra oil diets were: during RE - 0.78, 0.80, 0.79, respectively and during Ex - 0.91, 0.94, 0.92, respectively. On the basis of RQ there was no indication of preferential oxidation of fatty acids on either the canbra or soybean oil diets during Re or Ex. There also were no significant differences in energy consumption at the 0.01 confidence level between subjects when fed canbra oil or soybean oil. Serum glucose decreased while serum lactate and pyruvate increased during Ex on all three diets. There was no significant difference (α = .01) in lactate/pyruvate ratios between subjects fed canbra oil and soybean oil, indicating no change in muscular mitochondrial function. No consistant change in serum glycerol was observed during the experimental periods. Serum cholesterol, triglyceride and lipid phosphorus did not differ significantly (α = .01) due to experimental fat. All hematological parameters measured were within normal ranges. The present results indicate that canbra oil had no deleterious effect on the serum lipid patterns, whole blood hematology or energy metabolism at rest or under physical work, of young healthy college males.

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INTRODUCTION

Within the past five years rapeseed oil production has increased substantially in Canada. Estimated total disappearance figures for Canbra oil for 1972-3 was 300 million pounds with export accounting for about 0.25%. Rapeseed oil produced in Canada prior to 1972 was characterized by a high erucic acid content (38% of total fatty acid). As of January 1973 oil seed processors in Canada changed their entire production of rapeseed oil to varieties that are low in erucic acid (less than 5% of total fatty acids). This change to canbra oil, the name commonly applied to low erucic acid rapeseed oil, stemmed from the observations that long chain monoenoic acids, such as erucic acid, produced pathological changes in tissues that are predominantly dependant on fat for energy, namely the heart and skeletal muscle (Rocquelin and Cluzan, 1967; Abdellatif and Vles, 1970c; Beare-Rogers and Nera, 1972).

Pathological changes observed in laboratory animal species fed rapeseed oil has been attributed to the high level of erucic acid and the low level of saturated fatty acid in the oil. Although erucic acid alone undoubted can cause metabolic changes in the myocardium other factors in the oils of Crucifercae can not be excluded since canbra

oil also has been reported to have an unfavourable effect on the myocardium. Rocquelin and Cluzan (1967) found that canbra oil produced similar lesions to those of high erucic acid rapeseed oils, although the incidence and severity was much lower than for high erucic acid rapeseed oil. On the other hand, Abdellatif and Vles (1970c) did not find lesions with low erucic acid rapeseed.

The caloric value of fat in the human diet is taken as 9 kilocalories per gram regardless of fat source. Studies with other species have shown considerable variation among different fat sources in metabolizable energy content. The metabolizable energy of rapeseed oil for the chicken has been reported to be lower than that of beef tallow (Walker et al., 1970) and corn oil (Shephard et al., 1971). Houtsmuller (1970) has reported a decreased rate of oxygen consumption by isolated heart mitochondria from animals fed rapeseed oil. Trémolières et al. (1971) also reported differences in respiratory quotients between individuals fed a single meal of rapeseed oil and those fed a single meal of peanut oil.

Consumption of rapeseed oil by the average Canadian consumer was estimated in 1970 as only 7 grams per day. It is conceivable that this figure has increased recently. It has been known for years that rapeseed oil is well absorbed by the human (Deuel et al. 1949). Work in our laboratory has confirmed this finding and has shown that canbra is as efficiently absorbed by the human

as high erucic rapeseed oil when it accounts for approximately 58 per cent of the average daily fat intake (Vaisey et al., 1973).

The present study was designed to compare the effect of canbra oil and soybean oil on energy metabolism at rest and at a standardized work load. The fats tested constituted approximately 95 per cent of the total daily fat intake. This was accomplished by using diets consisting of meat analogues from soybean protein, egg albumin, skim milk and cereals as the primary sources of protein. The subjects participating in the study were 4 healthy male college students. Lipid metabolism was assessed by analysis of sera for total cholesterol, triglycerides and lipid phosphorus. Energy metabolism was assessed by determination of serum glucose and glycerol concentrations, respiratory quotient (RQ), oxygen consumption, and venous pyruvate and lactate concentrations.

REVIEW OF LITERATURE

A. Introduction

The Canadian production of rapeseed oil in 1971 surpassed the production of soybean oil and became the major edible oil of commerce in Canada. Rapeseed oil production has continued to increase since that time. Together soybean and rapeseed oils account for approximately 50 per cent of the total edible oil production in Canada. The Canadian diet is comprised of a large proportion of both soybean and rapeseed oils.

In 1973 Canadian oil seed growers replaced their traditional varieties of rape, high in erucic acid, by growing varieties low in erucic acid (less than 5% of total fatty acid). Canbra, the new oil, is today the only rapeseed oil sold commercially in Canada. Canbra oil is characterised by very low levels of erucic acid, a 22-carbon monoenoic fatty acid, and eicosenoic acid, a 20-carbon fatty acid. Canbra oil has a higher level of oleic acid than rapeseed oil; erucic and eicosenoic acids having been replaced by oleic acid in canbra oil. Like rapeseed oil, canbra oil has a low level of saturated fatty acids such as palmitic and stearic. Thus rapeseed and canbra oils differ from most vegetable oils in their content of saturated and unsaturated fatty acids.

B. Fatty Acid Composition of Rapeseed, Canbra and Soybean Oils

Both rapeseed oil and canbra oil are produced from Brassica campestris and Brassica napus species of rape. Both plants are similar in the kinds of fatty acids present in their seeds but differ in the proportion of these fatty acids. Traditional B. napus oil contains more erucic acid than traditional B. campestris oil (Table 1). Following the development of a new strain of B. napus low in erucic acid by Stefanson et al. (1961), several low erucic acid varieties have been developed in both the B. napus and B. campestris species. Both rapeseed and canbra oils differ from other vegetable oils in that they contain a lower level of saturated fatty acids.

A comparison of rapeseed oil and canbra oil (Table 1) indicates the main differences between the oils are the relative proportions of oleic, linoleic, eicosenoic and erucic acids. In canbra oil oleic accounts for 55-63% of the total fatty acids, whereas in the traditional rapeseed oil the major fatty acid, erucic acid, accounts for 30-40% of the total fatty acids. A similar comparison of canbra oil and soybean oil indicates a higher percentage of saturated fatty acids (palmitic and stearic acids) in soybean oil and a proportionally lower amount of unsaturated fatty acids than in canbra oil. The primary unsaturated fatty acids of canbra and soybean oils are oleic

Table 1

Fatty Acid Composition of Rapeseed, Canbra and Soybean Oils[1]

Fatty Acid %	Rapeseed Oils		Canbra Oil		Soya Oil
	B. Napus Nugget	B. Campestris Arlo	B. Napus	B. Campestris	
Palmitic, C16:0[2]	4	3	4.7	4.4	11.5
Stearic, C18:0	1	2	1.8	0.1	3.9
Oleic, C18:1	19	27	63.3	54.8	24.6
Linoleic, C18:2	14	18	20.0	31.1	52.0
Linolenic, C18:3	8	9	8.9	9.7	9.0
Eicosenoic, C20:1	14	12	1.3	-	-
Erucic, C22:1	40	31	-	-	-

[1]Data from Craig, 1970.

[2]Carbon number: number of double bonds.

and linoleic, respectively. Erucic and eicosenoic acids are not present in soybean oil. The linolenic acid content of the three oils is relatively similar.

C. Physiological Effects of High and Low Erucic Acid Rapeseed Oils

The physiological effects of high erucic acid rapeseed oil range from growth retardation and impaired digestibility of fat to severe myocardial changes. As early as 1947 Boer et al. reported poorer growth responses in laboratory animals fed rapeseed oil as compared to animals fed other fat sources. The effects of rapeseed oil and canbra oil on animal growth has been dealt with in depth by LeBlanc (1973). Thomasson and Boldingh (1955) suggested that growth retardation in animals fed rapeseed oil was associated with decreased food intake. Beare et al. (1957) found that although high levels of rapeseed oil consistently retarded weight gain, corrected body weight gain on the basis of the amount of food consumed by each rat still resulted in a significant difference in weight gains after three weeks on the rapeseed oil diet. Thus the results indicated a difference in the utilization of the rapeseed oil diets compared to other fat sources.

Canbra has been found not to depress growth in several animal species (Craig and Beare, 1968; Rocquelin and Cluzan, 1968; Kramer, 1973; Kramer et al. 1973). Feeding of canbra oil to experimental animals results

in higher food intake and weight gain than rapeseed oil. Furthermore, the addition of saturated fatty acids to canbra or interesterification of the simple triglycerides did not enhance its growth promoting effect (Craig and Beare, 1968).

Growth retardation in animals has been attributed to poor digestibility of high erucic acid rapeseed oil and to the degree of saturation of the rapeseed oil. Animal studies with rapeseed oil indicate low digestibility in the rat, the guinea pig and the pig, but not the dog (Carroll, 1953; Crampton et al., 1960; Hamilton and McDonald, 1969). Vaisey et al. (1973) working with human subjects have reported a digestibility coefficient of 98.7 and 99.9 for rapeseed and canbra oils, respectively. Animal studies investigating the digestibility of canbra oil are few. Rocquelin and Leclerc (1969) found the digestibility of canbra oil in the rat to be high, that is 96 per cent. Although the degree of saturation of rapeseed oil also has been considered responsible for the growth retarding effect of rapeseed oil (Hopkins et al., 1955; Murray et al., 1958) Craig and Beare (1968) found no growth depression in animals fed canbra oil though both canbra and rapeseed oils have the same degree of saturation. However Beare et al. (1963) using a diet containing no erucic acid showed that an imbalance in the ratio of saturated to unsaturated fatty acids could result in growth depression in animals.

Another physiological response to rapeseed oil is impaired reproduction. Carroll and Noble (1957) and Beare et al. (1959) have reported decreased spermatogensis in young and old rats. In the young rats decreased spermatogensis was not accompanied by depressed growth. Female rats were unaffected except for some difficulties with parturition.

More profound physiological changes which occur with the feeding of rapeseed oil are rapid accumulation of lipid in the myocardium, followed by histiocyte infiltration, myocardial necrosis and fibrosis. Degenerative changes in the myocardium have been reported also with the ingestion of canbra oil. However reports on changes in the myocardium of animals ingesting low erucic acid rapeseed oil are conflicting.

In 1967 and 1968 Rocquelin and Cluzan reported the presence of foci of histiocyte infiltration in the myocardium of rats fed rapeseed oil for a six-month period. However lipid accumulation in cardiac and skeletal muscles have been reported (Beare-Rogers, 1970; Abdellatif and Vles, 1970 a, c) to begin within a few hours after the feeding of rapeseed oil to rats. Lipid accumulation reached a peak after six days and then decreased to near normal levels within five to six weeks. Abdellatif and Vles (1970 a, c) and Beare-Rogers (1970) found that the stage of histiocyte infiltration described by Rocquelin and Cluzan (1968) was present after sixteen

weeks and that after thirty-two and sixty-four weeks interstitial replacement fibrosis of the myocardium was observed.

Myocardium lesions have been reported in a number of animal species fed rapeseed oil, although the extent and pattern of response differs with the species. Similar lesions described for the rat have been observed in the duckling (Abdellatif and Vles, 1970b; 1971; Abdellatif et al., 1972), miniature and regular baby pigs, gerbils and squirrel monkeys (Beare-Rogers and Nera, 1972), guinea pigs (Vles and Abdellatif, 1970b), and rabbits (Vles and Abdellatif, 1970a). Rocquelin and Cluzan (1971) and Rocquelin et al. (1970) have found degenerative changes in the heart muscle of rats fed canbra oil, although the changes were less pronounced than in rats fed rapeseed oil. Kramer et al. (1973) also found fat accumulation in the myocardium of male and female rats fed both high and low erucic and rapeseed oil. The fat accumulation was severe in rats fed rapeseed oil (22.3% erucic acid), moderate in those fed Span (4.3% erucic acid), and slight in those fed Oro (1.6% erucic acid). Unlike the erucate-induced lipidosis found in both sexes, necrotic and fibrotic lesions in the heart were observed more frequently in male rats fed rapeseed oil, Span or Oro for sixteen weeks (Kramer et al., 1973). However other investigators (Craig and Beare, 1968; Abdellatif and Vles, 1970c; Beare-Rogers et al., 1971) did not observe myocardial lesions in animals fed canbra oil.

Furthermore canbra oil did not induce cardiac lipidosis or mortality in rats subjected to cold stress (Beare-Rogers and Nera, 1974). Yet vacuolation and lipid infiltration have been observed in chickens after 14 days on a low erucic acid (1.2%) diet (Lall et al., 1972).

Numerous other changes have accompanied the ingestion of both high and low erucic acid rapeseed oils. Some of the changes accompanying the ingestion of high erucic acid rapeseed oil are steatosis of skeletal muscle, hemolytic anemia, steatosis and cortical hypertrophy of the adrenal glands in rats (Abdellatif and Vles, 1970c), cirrhosis of the liver in ducklings (Abdellatif and Vles, 1970b), hypertrophy of the spleen in guinea pigs (Vles and Abdellatif, 1970b), decreased ability to react to cold stress (Beare-Rogers and Nera, 1974), and erucic acid incorporation into both neutral lipids and phospholipids of the livers of rats (Kramer, 1973). The concentration of erucic acid in liver lipids was proportional to its concentration in the dietary rapeseed oils but at a much lower concentration (Kramer, 1973). Span and to a lesser extent Oro-containing diets also caused a temporary increase in liver lipids in rats (Kramer et al., 1973).

D. Metabolic Effects of Rapeseed and Canbra Oils

The metabolism of rapeseed oil has been extensively studied in in vitro and in vivo in laboratory animals. Much less work has been done with low erucic acid

rapeseed oil. Metabolism of rapeseed and canbra oils have been dealt with in depth by Huisman (1974) and LeBlanc (1973). This present section will deal primarily with the metabolic effect of rapeseed and canbra oils in humans although comparisons will be drawn from animal experiments.

It is not known whether ingestion of high levels of high erucic acid rapeseed oil will induce degenerative changes in the myocardium of humans. Experimentation with humans, for obvious reasons, has been restricted to investigating changes in blood parameters accompanying the ingestion of high erucic acid rapeseed oil. The most common parameters measured are whole blood hemotology and serum lipid patterns. Energy metabolism in humans given a single dose of high erucic acid rapeseed oil also has been investigated.

Review of the literature indicates that much of the work in metabolism is restricted to changes in serum lipid pattern as they reflect lipid metabolism. Malros and Wigand (1957) have reported a substantial decrease in serum cholesterol in human subjects after one week on a high erucic acid rapeseed oil diet following a hydrogenated coconut oil diet. However Grande et al. (1962) did not observe any marked difference in serum cholesterol and triglycerides in humans fed rapeseed oil or a mixture of corn and olive oil. Huisman (1974) found a transitory decrease in serum cholesterol, triglycerides and lipid phosphorus in subjects fed high erucic acid (32%) rapeseed

oil for 22 days, however the serum lipid levels on Day 32 were not different from Day 10. In contrast, LeBlanc (1973) observed a linear decrease in serum cholesterol and lipid phosphrous in human subjects fed canbra oil for 22 days. Serum triglycerides on the canbra oil diet only decreased slightly over the 22 day period. Phospholipid fatty acid patterns show a substantial increase in oleic acid in response to the rapeseed (Huisman, 1974) and canbra (LeBlanc, 1973) oil diets. The change coincided with the high levels of monoenoic fatty acids in the rapeseed and canbra oils. On the canbra oil diet decreases in palmitic and stearic acids were observed in the phospholipid fraction. These changes coincided with the lower levels of these fatty acids in the canbra oil diet than in the mixed fat diet. On both the rapeseed oil and canbra oil diets only small amounts of eicosenoic acid was found in the phospholipid fraction. No erucic acid was found in the serum phospholipid fraction from subjects fed canbra (LeBlanc, 1973), whereas 1.5 per cent of erucic acid was present in the serum phospholipid fraction from subjects fed high erucic acid rapeseed oil (Huisman, 1974). Low levels of eicosenoic and erucic acids also have been reported in serum phospholipids of rats (Walker, 1972; Rocquelin et al., 1974). Table 2 compares the percentage fatty acid composition of serum phospholipids in humans and rats fed rapeseed and canbra oils.

Table 2

Per Cent Fatty Acid Composition of Serum Phospholipids in Humans and Rats Fed Rapeseed and Canbra Oils.

	Days on Diet	Fatty Acids									
		C16:0[1]	C16:1	C18:0	C18:1	C18:2	C18:3	C20:1	C20:3	C20:4	C22:1
		%									
Rapeseed											
Human[2]	21	21.4	1.4	12.0	23.7	24.4	1.0	3.5	1.6	6.2	1.5
Rat[3]	15	17.3	1.4	16.0	9.5	15.3	0.3	3.0	0.9	11.9	6.5
Canbra											
Human[4]	21	19.6	2.0	12.9	19.2	20.9	-	1.6	2.4	8.8	-
Rat[3]	15	19.3	0.5	21.6	10.7	17.5	0.4	1.0	1.4	15.1	0.9

[1]Carbon number: number of double bonds.

[2]Adapted from Huisman, 1974.

[3]Adapted from Rocquelin et al., 1974.

[4]Adapted from LeBlanc, 1973.

Rocquelin et al. (1974) studying the effect of rapeseed oil and canbra oil on serum lipids in rats indicated that feeding male rats rapeseed oil (15 per cent by weight of the diet) for two months did not influence the plasma content of triglycerides, phospholipids, nonesterified fatty acids and cholesterol esters, as compared to canbra oil. There was however a change in the fatty acid spectra, erucic acid and eicosenoic acids from the dietary rapeseed oil were incorporated mainly in the triglyceride and nonesterified fatty acid, with a lesser amount in the phospholipids and practically none in the cholesterol esters. The authors concluded that the immediate but temporary cardiac steatosis observed in rats fed rapeseed oil could not be explained by changes of the plasma triglycerides and nonesterified fatty acids concentrations and/or the fatty acid composition of these fractions. However both rapeseed oil and canbra oil increased the percentage of the omega--3 polyunsaturated fatty acids in plasma phospholipids.

During trierucin administration in rats, erucic acid accumulates to a large extent in the heart muscle with smaller amounts accumulating in the kidneys and adipose tissues (Jaillard et al., 1973). It was suggested (Jaillard et al., 1973) that these observations were related to a slow catabolism of erucic acid by the myocardium. Jaillard et al. (1973) also have suggested that certain long chain fatty acids such as erucic acid may be subjected to a preliminary

extra-mitochondrial oxidation, involving a shortening of chain length before being oxidized in the mitochondria. The decrease in accumulation of cardiac lipids after the second week of dietary manipulation indicated an enzymatic adaptation of the myocandium. In their experimentation with humans Jaillard et al. (1973) found that the myocardial uptake of free erucic acid was similar to other fatty acids though slightly less than oleic acid.

The metabolism of dietary docosenoic acid has been studied by Craig and Beare (1967). The oxidation of erucic acid produces fatty acids normally present in mammalian tissue such as 11-eicosenoic and oleic acids. The significantly higher level of oleic acid in hepatic lipids of rats fed rapeseed oil compared to those fed corn oil or lard suggest a rapid beta-oxidation of erucic and eicosenoic acids to oleic acid (Kramer, 1973). Because the changes in fat metabolism observed in experimental animals fed rapeseed oil are observed primarily in heart and skeletal muscles, it is possible that erucic acid is less efficiently oxidized and therefore accumulates in the triglycerides (Swarttouw, 1974). Accumulation of fat in tissues associated with the feeding of high erucic acid rapeseed oil may be due not only to reduced rates of oxidation of this fatty acid but also to low levels of triglyceride lipase activity for erucic acid (Kramer, et al., 1973), the inhibitory effect of erucic acid on the metabolism of other long-chain fatty acids (Christophersen and Bremer, 1972)

and impaired respiratory activity (Houtsmuller et al. 1970). Kramer et al. (1973) have reported that the enzymes of fatty acid activation and oxidation have a greatly reduced activity for erucic acid. However the reduction in tissue lipid observed after prolonged feeding of rapeseed oil may well be related to the increased activities of fat metabolising enzymes. Postheparin lipoprotein lipase activity increased after 6 days in rats fed rapeseed oil (Struijk et al., 1973).

Christophersen and Bremer (1972) have reported a slower rate of metabolism of erucic acid than palmitic acid in heart and liver mitochondria of rats fed rapeseed oil. There was a much slower oxygen uptake in both heart and liver mitochondria, and a slower rise in the intramitochondrial long-chain acyl-CoA level when erucylcarnitine served as substrate. Houtsmuller et al. (1970) have reported that heart mitochondria isolated from rats fed erucic acid have impaired respiratory activity with a number of substrates (glutamate, oxaloglutarate, decanoate, succinate, malate). Other investigators (Kramer et al., 1973) have observed decreases in palmityl carnitine oxidation in the heart mitochrondia of rats fed high erucic acid rapeseed oil. However in no case was a marked depression in respiratory activity observed like that recorded by Houtsmuller et al. (1970). The discrepancy between these observations may have been the result of improper mitochondrial isolation (Kramer et al., 1973).

Erucylarnitine also was a poorer substrate for long-chain carnitine acyltransferase than palmitylcarnitine (Christophersen and Bremer, 1972). These authors (Christophersen and Bremer, 1972) also found that oxygen uptake by liver mitochondria in the presence of palmitylcarnitine was inhibited more by erucylcarnitine when malonate was present than with malate suggesting an inhibition of the beta-oxidation of palmitate rather than an inhibition of the tricarboxylic acid cycle. That erucylcarnitine inhibited the mitochondrial oxidation of palmitate to a greater extent in the heart mitochondria than in liver mitochondria may account for the cardiac pathophysiological findings reported in the literature. Swarttouw (1974) does not rule out the possibility that differences in transport of fatty acids to the site of oxidation may account for the preferential oxidation of palmitate or oleate in the presence of erucate since impaired oxidation of erucate does not fully explain the preferential oxidation of palmitate or oleate in its presence.

Tremolieres et al. (1971) investigating the effect of a single dose of high erucic acid rapeseed oil on respiratory exchange in man, observed that RQs decreased during rest and then rose during mild exercise. Subjects fed peanut oil did not experience a similar decrease in RQ during rest, and their RQs during exercise were higher than those observed after the feeding of rapeseed oil. The lower RQ during exercise after the ingestion of rapeseed oil was interpreted as

preferential oxidation of fatty acids in the rapeseed oil. The fact that neither the plasma lactate and pyruvate concentrations nor their ratios were altered indicated that the muscle mitochondria were capable of standing the increase in glucose oxidation (Tremolieres et al., 1971). Tremolieres et al. (1971) also reported lower oxygen consumption during exercise after the administration of rapeseed oil than peanut oil.

The reports in the literature are too scant to draw any conclusions about respiratory changes or energy metabolism in man as a consequence of the ingestion of rapeseed oil. However the observations were taken as justification for studying respiratory exchange and energy metabolism in men ingesting the low erucic acid rapeseed oil sold commercially in Canada.

E. Aerobic Metabolism

The amount of oxygen consumed during a given quantity of work reflects only the energy derived through the aerobic metabolic pathway. There are in addition to the aerobic pathway, two anaerobic pathways from which the body can derive its energy, namely, the lactacid energy source (energy derived from the metabolic conversion of pyruvate $\rightleftharpoons$ lactate) and the alactacid energy source (energy derived from the body stores of adenosine triphosphate and creatine phosphate without the formation of lactic acid). The work of Bason et al. (1971) indicates that there is a reciprocal relationship between the

aerobic and anaerobic energy sources. As the energy from aerobic metabolism is reduced with increased hypoxia, the energy derived from anaerobic metabolism is increased to counter-balance this decrease so that the total-energy input for a given amount of work remains unaffected by hypoxia.

The source of energy for muscular contraction is the splitting of adenosine triphosphate (ATP). ATP can be quickly resynthesized by the breakdown of creatine phosphate (CP). The ultimate sources of energy for ATP resynthesis are fat and carbohydrate. During exercise the turnover of ATP and CP in the muscle cells is increased. Thus at the onset of exercise the phosphagen stores (ATP and CP) play an important role in covering part of the anaerobic energy release (Karlsson et al., 1970). Some investigators (Lardy and Wellman, 1952, 1953; Chance, 1957) believe that intracellular respiration is regulated by intracellular levels of ATP, adenosine diphophate (ADP) and inorganic phosphate (Pi). Changes in the ratio of ATP/(ADP + Pi) control the rate of oxygen uptake; the rate being inversely proportional to the ratio. Under normal conditions the transition from rest to exercise results in ADP and Pi going from relatively low concentrations to progressively higher concentrations as ATP and CP split to provide the necessary energy for work. The levels of ADP and Pi continue to increase until electron transport

and oxidative phosphorylation increase concomitantly to balance the rate of ATP breakdown (Bason et al., 1973). To function properly the electron transport system needs oxygen, thus oxygen uptake parallels the rate of electron transport. When the rate of ATP splitting is equal to the rate of resynthesis a condition of steady-state oxygen consumption is reached. Under conditions of steady-state in the working muscle there is a higher concentration of split phosphagens than at rest. Opinions vary regarding the factors affecting the time to steady-state. Wasserman et al. (1967) have shown that the time to steady-state is related to the intensity of the work, being more prolonged for higher work intensities. On the contrary Di Prampers et al. (1970) have demonstrated that oxygen consumption increased with a definite time course following the onset of exercise, reaching a steady-state in a relatively short period of time. When work begins at a pace set mechanically by a device like the treadmill the output of energy reaches full scale almost immediately, however oxygen uptake increases gradually. The lag in oxygen consumption may be due to the delay in circulatory adaptation in the working muscles. The initial oxygen uptake appears to be limited by the supply of oxygen to the muscle (Craig, 1972).

Bailey et al. (1973) like other investigators (Aschoff and Pohl, 1970) have reported that oxygen consumption in humans in the postabsorptive state is not constant

but subjected to cyclic variations. From their findings Bailey et al. (1973) have concluded that the diurnal rise in oxygen consumption and the two hour cycles may be of practical importance. These authors suggest that experiments investigating oxygen consumption should be planned for a minimum of 120 minutes to account for the variation from peak to peak and trough to trough.

When the energy requirements of muscle exceed the rate of aerobic oxidation, the additional energy required will be supplied by an increased rate of anaerobic glycolysis resulting in the production of lactic acid. As the oxygen stores of the muscles and blood are utilized mainly in the first minute of exercise (Astrand et al., 1960) the greatest involvement of anaerobic energy sources would occur after the first minute and before the steady-state condition is reached. This period is characterised by high levels of oxygen debt. At work intensities up to 74% of maximum oxygen uptake the peak in lactic acid production coincides with the peak in oxygen debt (Whipp et al., 1970).

It was demonstrated a quarter century ago that blood lactate levels depend on the rate of formation of lactate in the working muscle, the rate of cellular utilization and excretion and the rate of diffusion of lactate into the blood and adjacent tissues (Strom, 1949). Although it was thought that lactate was not produced in

the muscle during submaximal exercise or until all the phosphagen stores were depleted (Margaria, 1967), Karlsson (1971) and Knuttgen and Saltin (1972) observed increases in blood lactate levels before phosphagen stores were depleted. Knuttgen (1962) found that lactate did not accumulate until an oxygen consumption of 1.5 liters/min. was obtained. It is not clear what causes the discrepancies observed in lactate accumulation. Some suggestions are, differences in experimental design, duration and intensity of exercise, and physical fitness of the subjects.

The measurement of respiratory exchange and other parameters measuring aerobic (oxygen consumption) and anaerobic (changes in serum lactate and pyruvate concentrations) metabolism might be a way of assessing energy metabolism in men ingesting canbra oil.

OBJECTIVE OF RESEARCH

The objectives of the study described herein were:

(1) to investigate the effect of dietary fat source, in particular low erucic acid rapeseed oil, on energy metabolism and serum lipid response in young men;

(2) to determine the effect of a standardized work load on energy metabolism; and

(3) to measure energy metabolism in response to a single meal of dietary fat.

EXPERIMENTAL METHODS

A. Experimental Design

The 32-day metabolic study including four healthy male subjects was divided into three experimental periods. The first 10 days of the study served as a stabilization period when the subjects were fed a mixed fat diet. During the stabilization period the subjects were introduced to the routine of the study and caloric requirements were adjusted to meet individual requirements. Following the stabilization period two of the four subjects were put on a canbra oil diet and two on a soybean oil diet for 11 days, Experimental Period I. The diets were then switched for the final 11 days, Experimental Period II. Thus the two subjects fed canbra oil in the first period received soybean oil during the second period, and those fed soybean oil in Period I received canbra oil during Period II.

Prior to starting the metabolic study the subjects were instructed in adhering to the dietary regimen throughout the study. The subjects resided in their own homes and maintained their normal activity, with any unusual activity recorded for reference. All meals, with the exception of Saturday and Sunday evening meals were served in the Home Economics Building, the University of Manitoba. Saturday and

Sunday evening meals were packaged for home preparation by the subjects. The subjects were weighed daily before breakfast. Body weight was maintained for each subject by adjusting the individual's carbohydrate and fat intake. A two-day menu (Table 3) was used throughout the stabilization and experimental periods with a special test day menu including a test meal containing 68 gm. of test fat being fed on each exercise day.

On the first day of each dietary regimen and again two days before the end of each dietary regimen the subjects were exercised at 66% of their maximal oxygen uptake on a bicycle ergometer (950 kilopond meters/minute was consistant for all subjects because they were all in the same fitness category), for ten minutes, 2.5 hours after a meal containing 68 grams of the test fat. The subjects were initially familiarized with the bicycle ergometer and metabolic equipment in order to assess their respective work loads (Work Tests With The Bicycle Ergometer, by P. O. Astrand).[1] All tests were conducted in an air-conditioned laboratory, thus environmental conditions (temperature and humidity) were consistant except for barometric pressure which was corrected in gas analysis. Each exercise period was preceded by a twenty-minute rest period and followed by a twenty-minute recovery period. Respiratory exchange

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[1]Monark-Crescent, A. B. Varberg, Sweden.

Table 3

Composition of Diets

Menu I	Menu II
Breakfast[1]	
125 ml. Unsweetened Orange Juice	125 ml. Apple Juice
Cream of Wheat[2]	Cooked Rolled Oats[2]
Scrambled Egg Albumin[2]	Scrambled Egg Albumin[2]
1 Slice White Bread	1 Slice White Bread
239 ml. Skim Milk	239 ml. Skim Milk
20 gm. Strawberry Jam	20 gm. Marmalade
14 gm. Brown Sugar	14 gm. Brown Sugar
14 gm. White Sugar	14 gm. White Sugar
25 gm. Butter or Margarine[3] (for day)	25 gm. Butter or Margarine[3] (for day)
Lunch[1]	
Scalloped Potatoes[2]	Spaghetti with Tomato Sauce[2]
100 gm. Green Beans[2]	50 gm. Tossed Salad: Lettuce and Tomato[2]
100 gm. Fruit Cocktail + 10 ml. Syrup	Oil and Vinegar Dressing[2]
1 Slice White Bread	100 gm. Peaches + 10 ml. Syrup
239 ml. Skim Milk	1 Slice White Bread
	239 ml. Skim Milk
Supper[1]	
Sweet and Sour Pork[2]	Beef Stew[2]
Rice[2]	Instant Mashed Potato[2]
100 gm. Tossed Salad: Lettuce and Tomato[2]	65 gm. Cole Slaw[2]
Oil and Vinegar Dressing[2]	Oil and Vinegar Dressing[2]
100 mg. Plums + 10 gm. Syrup	1 Apple (approx. 175 gm.)
1 Slice White Bread	1 Slice White Bread
239 ml. Skim Milk	239 ml. Skim Milk

Table 3 (Concl'd)

Snacks[1]

2 Cup Cakes[2]
2 Raisin Oatmeal Cookies[2]
1 Spicy Fruit Square[2]

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[1]Coffee and tea allowed ad. lib. Alcohol and other beverages prohibited.

[2]As prescribed in recipe (Appendix Tables 1-17).

[3]25 gm. Butter as spread for day per Mixed Fat Diet; 25 gm. Soybean Margarine as spread for day per Soybean Oil Diet; 25 gm. Canbra Margarine as spread per day for Canbra Oil Diet.

Table 4

Composition of Test Day Menu

Breakfast[1]

125 ml. Apple Juice
Scrambled Egg Albumin[2]
1 ½ Slices White Bread
10 gm. Butter[3]
20 gm. Strawberry Jam or Marmalade OR 14 gm. White Sugar

Mid-Morning Snack[1]

1 Apple (Approx. 175 gm.)
1 Slice White Bread
20 gm. Strawberry Jam or Marmalade

Test-Meal[1]

Beef Stew[2]
Instant Mashed Potatoes[2]
65 gm. Cole Slaw[2]
Oil and Vinegar Dressing[2]
100 gm. Peach + 10 ml. Syrup
1 Slice White Bread
239 ml. Skim Milk
15 gm. Butter or Margarine[3]
5 gm. White Sugar

Take Home Snack

2 Cup Cakes[2]
2 Raisin Oatmeal Cookies[2]
1 Spicy Fruit Square[2]
1 Regular 7 Up

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[1]Coffee and tea allowed ad. lib. Alcohol and other beverages prohibited.

[2]As prescribed in recipe (Appendix tables 1-16).

[3]10 gm. Butter as spread was served for all exercise days.

measurements were monitered throughout the rest, exercise and recovery periods. Heart rate was continually monitered by an electrocardiograph[2] (three-electrode system). The subjects were worked at a heart rate of 165 ± 5 during the exercise period. In addition on the morning of the first and last days of experimental period II respiratory exchange measurements were monitered after an overnight fast. Blood samples were taken during the rest period, within thirty seconds following exercise and at the conclusion of the recovery period. Blood samples were analysed for glucose, glycerol, lactate and pyruvate concentrations.

Fasting blood samples were taken before breakfast on the first day of the experiment and at the end of each dietary regimen (Figure 1). The sera were analysed for cholesterol, triglycerides, and lipid phosphorus. In addition whole blood hematology and metabolites were determined on fasting blood samples.

B. Subjects

The subjects participating in the study were four male college students, selected from respondants to posted notices. The subjects were chosen for the study on the basis of an interview with the project director, a

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[2]Exercise Cardio Tachometer, Quinton Instruments, Montreal, Model 609, with a Quinton Electrocardiograph isolation amplifier, Model 620 and a Cambridge VS 4 Electrocardiograph tracer.

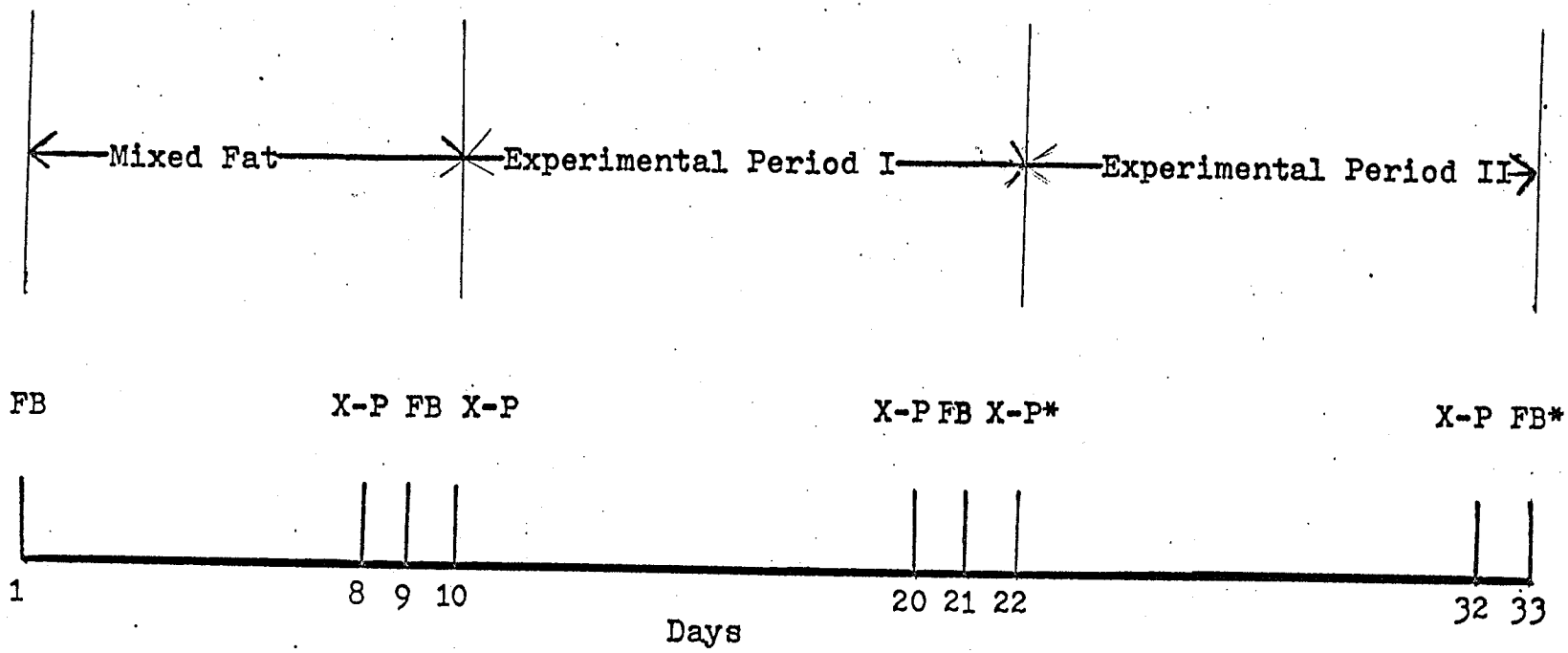

Figure 1. Experimental Design

Symbol: FB - fasting blood; X-P - exercise protocol
Mixed fat diet - all 4 subjects.
Experimental Period I - Soybean oil diet - H.R. and G.C.;
Canbra oil diet - T.T. and S.M.
Experimental Period II - Canbra oil diet - H.R. and G.C.;
Soybean oil diet - T.T. and S.M.
* - Fasting (Rest) respiratory exchange.

physical examination and expressed cooperativeness. The subjects were without diagnosed metabolic disorders or recent history of poor health. They ranged in age from 20-26 years (average age 23.5 years). Physical data for the subjects is presented in Table 5.

C. Test Fats

The fat sources (Table 6) used for the mixed fat diet were lard, vegetable shortening, beef tallow, butter and corn oil. Per cent composition and per cent fatty acid composition of the fat mixture are presented in Tables 6 and 7. Canbra oil, specially prepared canbra margarine, soybean oil and soybean margarine were the sole added fat source to the canbra oil and soybean oil diets. Fatty acid composition of canbra oil and margarine are presented in Tables 8 and 9. Fatty acid composition of soybean oil and margarine are presented in Tables 10 and 11.

D. Diet Composition

The solid test diet (Table 3) used in this study was similar to the diets used by Ravensdale (1972), LeBlanc (1973) and Huisman (1974). However the amount of textured vegetable protein (TVP)[3] was reduced because of reported problems with flatulence.

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[3]Trade name for Textured Vegetable Protein. Archer Daniels Midlands Co., 733 Marquette Ave., Minneapolis, Minnesota, 55440.

Table 5

Physical Data of Subjects

Subject	Age (Yr.)	Height (cm)	Weight (Kg)		
			Initial	Mean during Canbra Oil Diet	Mean during Soybean Oil Diet
G.C.	25	180	71.5	70.1 ± 0.9[1]	70.2 ± 0.8[1]
H.R.	23	170	64.8	64.7 ± 0.5	64.8 ± 0.7
T.T.	20	180	76.3	75.7 ± 0.8	75.5 ± 0.8
S.M.	26	180	80.8	78.9 ± 1.0	78.3 ± 0.8

[1]Mean ± S.D. for 11 daily weighings.

Table 6

Composition of Fat Mixture

Ingredients	Per Cent
Butter[1]	39.8
Vegetable Shortening[2]	21.3
Lard[3]	17.0
Corn Oil[4]	13.3
Tallow[5]	8.6
Sat.: Oleic: Linoleic	2.5: 2.4: 1.0

[1]Modern, Canada Safeway Ltd., Winnipeg, Manitoba

[2]Crisco, Proctor and Gamble, Toronto, Ontario.

[3]Tenderflake, Canada Packers Ltd., Toronto, Ontario.

[4]Mazola, Best Foods Division, Canada Starch Co. Ltd., Montreal, Quebec.

[5]Bleached, clarified, deodorized, Canada Packers Ltd., Winnipeg, Manitoba.

Table 7

Fatty Acid Composition of Fat Mixture

Fatty Acid	% of Total Fatty Acids
Decanoic, C10:0[1]	1.5
Lauric, C12:0	1.6
Myristic, C14:0	5.1
Palmitic, C16:0	21.5
Palmitoleic, C16:1	2.1
Stearic, C18:0	12.5
Oleic, C18:1	35.2
Linoleic, C18:2	16.3
Linolenic,[2] C18:3	1.0
Eicosenoic, C20:1	1.0

[1]Carbon Number: number of double bonds.

[2]Not distinguished from C20:0 with the column used to resolve fatty acids.

Table 8

Fatty Acid Composition of Canbra Oil[1]

Fatty Acid	% of Total Fatty Acid
Myristic, C14:0[2]	0.1
Palmitic, C16:0	4.6
Palmitoleic, C16:1	0.2
Stearic, C18:0	2.1
Oleic, C18:1	62.6
Linoleic, C18:2	20.6
Linolenic,[3] C18:3	8.2
Eicosenoic, C20:1	1.3
Behenic, C22:0	0.1
Erucic, C22:1	0.4

[1]Prepared from B. napus cv. Zephyr, Canada Packers Ltd., Winnipeg, Manitoba.

[2]Carbon Number: number of double bonds.

[3]Not distinguished from C20:0 with the column used to resolve fatty acids.

Table 9

Fatty Acid Composition of Canbra Margarine[1]

Fatty Acid	% of Total Fatty Acid
Myristic C14:0[2]	0.1
Palmitic C16:0	6.0
Palmitoleic C16:1	0.3
Stearic C18:0	10.0
Oleic C18:1	67.5
Linoleic C18:2	7.5
Linolenic[3] C18:3	1.3
Eicosenoic C20:1	2.8
Behenic C22:0	0.3
Erucic C22:1	4.1

[1]Prepared from B.napus cv. Zephyr and supplied through the courtesy of Agro Industries, Nipawin, Saskatchewan.

[2]Cabon Number: number of double bonds.

[3]Not distinguished from C20:0 with the columna used to resolve fatty acids.

Table 10

Fatty Acid Composition of Soybean Oil[1]

Fatty Acid	% of Total Fatty Acid
Palmitic, C16:0[2]	9.3
Stearic, C18:0	3.6
Oleic, C18:1	49.5
Linoleic, C18:2	34.8
Linolenic,[3] C18:3	2.8

[1]Crisco Oil. Proctor and Gamble, Toronto, Ontario. (Purchased on the local market)

[2]Carbon Number: number of double bonds.

[3]Not distinguished from C20:0 with the column used to resolve fatty acids.

Table 11

Fatty Acid Composition of Soybean Margarine[1]

Fatty Acid	% of Total Fatty Acid
Lauric, C12:0[2]	0.7
Myristic, C14:0	0.5
Palmitic, C16:0	11.6
Palmitoleic, C16:1	0.5
Stearic, C18:0	9.8
Oleic, C18:1	36.8
Linoleic, C18:2	34.0
Linolenic[3] C18:3	5.6
Eicosenoic, C20:1	0.2

[1]Butternut. Canada Packers Ltd., Winnipeg, Manitoba.

[2]Carbon Number: number of double bonds.

[3]Not distinguished from C20:0 with the columns used to resolve fatty acids.

In addition, the ratio of saturated: oleic: linoleic fatty acids used by Le Blanc (1973) in her mixed fat diet and reported in the literature (Table 12) to resemble the fatty acid pattern of the North American diet was changed following the substantial decrease in serum cholesterol observed by Le Blanc (1973). Thus the diet used in this study was formulated using the fats listed in Table 6 to have a ratio of 2.5:2.4:1.0 for saturated: oleic: linoleic.

A two-day menu (Table 3) was used, with each menu designed to provide approximately thirty-eight per cent of the calories from fat. The experimental diets were similar to the mixed fat diet with the exception that the fats used in the mixed fat diet were replaced by the test fats; canbra oil and margarine (canbra oil diet) and soybean oil and margarine (soybean oil diet). The ratio of classes of fatty acids and the primary differences in fatty acid composition of the mixed fat and experimental diets are presented in Tables 13 and 14.

Bread was included at each meal to utilize the spread (butter, canbra or soybean margarines) and to wipe up any visible fat remaining on serving dishes.

On the days when the subjects were exercised the distribution of dietary fat (Test Meal Meanu Table 4) was different from either Menu I or Menu II (Table 3). Fifty-four per cent of the total fat intake for the day or 68 grams was fed in a single meal (Test Meal) 2.5 hours prior to each exercise protocol. These changes in the distribution of fat in the diets occurred on the eighth day of the stabilization period and on the first and tenth day of experimental periods I and II. Thus, the subjects were exercised on the first day of experimental periods I and II after a single meal of the test fat. On the tenth day of experimental periods I and II they were exercised following a similar schedule (that is, 2.5 hours after the test meal) except that they had received the test fat for the intervening nine days. The exercise protocol on the eighth day of the stabilization period was the same as the tenth day on the experimental periods except that the mixed fat diet was fed.

Table 12

Relative Proportions of Fatty Acids in Mixed Fat Diet

	Sat.	Oleic	Linoleic
Literature Values[1]	2.0	1.9	1.1
Calculated	2.5	2.4	1.0
Analyzed	2.6	2.2	1.0

[1]Based on, Call, D. R. and Sanchez, A. M. 1967 Trends in fat disappearance in the United States, 1909-65. J. Nutr. 93: Suppl. I, Part II.

Table 13

Ratio of Classes of Fatty Acids in Mixed Fat and Experimental Diets

Diet Menus		Ratios of fatty acid classes		
		Saturated	Monounsaturated	Polyunsaturated
Mixed Fat -	Menu I	1.0	1.1	0.7
	Menu II	1.0	1.1	0.6
Soybean	Menu I	1.0	2.4	2.1
	Menu II	1.0	2.5	2.1
Canbra	Menu I	1.0	6.2	1.5
	Menu II	1.0	5.4	1.7

Table 14

Per Cent Fatty Acid Composition of Mixed Fat, Soybean and Canbra Oil Diets

Fatty Acid	Per Cent Composition		
	Mixed Fat Diet	Soybean Oil Diet	Canbra Oil Diet
Lauric, C12:0[1]	0.1	0.3	tr
Myristic, C14:0	2.8	0.3	0.1
Palmitic, C16:0	19.8	10.7	6.8
Palmitoleic, C16:1	1.3	tr	0.1
Stearic, C18:0	13.0	6.8	6.0
Oleic, C18:1	38.0	44.4	64.9
Linoleic, C18:2	21.9	33.4	14.1
Linolenic, C18:3	1.3	4.0	4.7
Eicosenoic, C20:1	tr	tr	1.8
Erucic, C22:1	-	-	1.6
Ratio, Sat:Unsat.	1.0:1.8	1.0:4.6	1.0:6.8

[1]Carbon number: number of double bonds.

Table 15

Calorie and Nutrient Composition of Test Meal[1]

Composition	Test Meal	Total Intake for Test Day
Calories	1030	2740
Protein (g)	32.0	82.0
Fat (g)	68.0	100.0
Carbohydrate (g)	84.0	385.0
Calcium (mg)	430.0	1250.0
Phosphrous (mg)	440.0	1195.0
Iron (mg)	4.0	12.0
Vit. A. (µg RE)	2480.0	2790.0
Thiamin (mg)	0.5	1.2
Riboflavin (mg)	0.7	2.4
Niacin (mg)	24	59
Vit. C. (mg)	71.0	85.0

[1]Calculated values using U.S.D.A. Handbook #8 Composition of Foods (Watt and Merrill, 1963).

The daily menus were designed to include all food groups and to provide texture and flavor. All recommended daily nutrient intakes (Table 16) were met.

In addition to three meals served at customary hours throughout the day, each subject received three snack items daily for between meals and post-dinner snacks. All food items were prepared by standardized recipes (Appendix Tables 1-17).

Powdered skim milk, spray-dried egg albumin,[4] TVP and cereals were the primary sources of protein. The relative fat-free nature of these products ensured that the added fat accounted for 95% of the fat present in the diets. The TVP was hydrated with water, the appropriate fat added and the mixture incorporated into the Beef Stew and Sweet and Sour Pork entrees. The Scalloped Potatoes and Spaghetti with Tomato Sauce entrees did not contain any TVP.

Three entrees, Sweet and Sour Pork, Spaghetti with Tomato Sauce and Beef Stew were prepared in advance in individual foil containers,[5] frozen and stored as described by Le Blanc (1973). For meal service the entrees

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[4]Cham Foods Ltd., Jarvis St., Winnipeg, Manitoba.

[5]EKCO Foil Containers with Lids, Price Wilson Ltd., 830 King Edward St., Winnipeg, Manitoba. Sizes 685 LL and 705-35.

Table 16

Calorie and Nutrient Composition of Experimental Diet[1]

Composition	Menu Day I	Menu Day II	Recommended[2]
Calories	3090	2960	3000
Protein (g)	84	85	56.0
Fat (g)	126	126	-
Carbohydrate (g)	405	370	-
Calcium (mg)	1216	1250	800
Phosphorus (mg)	1140	1350	800
Iron (mg)	20	14	10.0
Vit. A. (μg RE)	1425	3730	1000
Thiamin (mg)	1.3	1.5	1.5
Riboflavin (mg)	2.3	2.5	1.8
Niacin (mg)	63	70	20
Vit. C. (mg)	122	138	30

[1]Calculated values using U.S.D.A. Handbook #8 Composition of Foods (Watt and Merrill, 1963).

[2]Recommended Daily Nutrient Intakes - Revised 1974. Recommendations assumes characteristic activity pattern for males of age group 19-35 years.

were heated as described in the recipes (Appendix Tables 6, 10 and 11).

E. Meal Analysis

Composites of each daily menu (including the menu used on exercise days) for the mixed fat, canbra and soybean diets were made. The individual food items were weighed to the nearest gram on a Sartorius top-loading balance.[6] The composites of each daily menu were homogenized with approximately 200 ml. of hot distilled water in a one-gallon Waring commercial blender.[7] Between 150-200 grams of the homogenate was lyophilized in a Virtis Freeze Drier.[8] Lyophilized samples were stored in plastic containers at -10°C for later analysis.

The method of Bligh and Dyer (1959) was used to extract total lipid from the lyophilized food samples. Methyl esters of the fatty acids were prepared according to the method of Metcalfe et al. (1966). The fatty acid methyl esters were dissolved in petroleum ether and stored for later analyses by gas-liquid chromotography as described by LeBlanc (1973). The individual fatty acids were identified by comparing retention times with known fatty acid mixtures.[9] The per cent fatty acid composition and

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[6]Model 2254, Sartorius-Werke A.G., Gottingen, Germany.

[7]Model CB-5. Waring Products Co., Winsted, Connecticutt.

[8]Model 10-140 MR-BA, Virtis Co. Inc., Gardiner, New York. 12525

[9]Hormel Institute, Lipids Preparation Laboratory, 801-16th Ave. N.E., Austin, Minnesota 55912.

total fat content of the mixed fat and experimental diets are presented in Tables 14 and 17.

F. Respiratory Gas Measurements and Analyses

F.1.a. Respiratory gas measurements were made on Days 8, 10, 20, 22 and 32 (Figure 1). During the fifty-minute exercise protocol all expired gas was channelled through a low resistance mouthpiece[10] to a Kafranyi-Michaelis gas meter[11] for determining volume and collecting a sample of gas for the Sholander determination. Respiratory gas was analysed for per cent oxygen and carbon dioxide. During the rest period the subjects remained in a sitting position. Immediately following the rest period the subjects bicycled for ten minutes at a standardized work load. During the recovery period the subjects again rested in a sitting position.

F.2.a. Respiratory gas analyses. Respiratory Quotient (RQ). RQ was determined using the method described by Sholander (1947) and using the Sholander equipment.[12]

$$RQ = \frac{\%\ CO_2 \text{ exhaled air} - 0.03}{\%\ N_2 \text{ exhaled air} \times 0.265 - \%\ O_2 \text{ exhaled air}}$$

where 0.03 is % CO_2 in atmospheric air and 0.265 is the ratio of O_2 to N_2 in atmospheric air.

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[10]Modified Otis-McKerrow Valve. W. E. Collins, Inc., 220 Wood Road, Braintree, Mass.

[11]Serial No. 721430. Gottingen, Germany.

[12]Scientific Instruments, 80 Swarthmore Ave., Rutledge, Pa.

Table 17

Total Daily Fat Intake

Diet	Calculated (g)	Analyzed[1] (g)	% Difference[2]
Mixed Fat			
Menu I	126.0	115.0	8.8
Menu II	126.0	118.0	6.5
Soybean			
Menu I	126.0	116.0	8.0
Menu II	126.0	116.5	7.7
Canbra			
Menu I	126.0	116.0	8.0
Menu II	126.0	119.4	5.4

[1] Results obtained by the Bligh and Dyer Method (1959).

[2] Per cent difference between analyzed and calculated values.

F.2.b. Ventilation Rate. The volume of expired air was monitored by the Kafronyi-Michaelis Gas Meter. The total volume of expired air was divided by the appropriate time period (minutes) to give the average ventilation rate (l/min.).

F.2.c. Oxygen consumption which reflects the rate of energy expenditure was determined for ventilation rate and the percentage of oxygen removed from the inspired air during breathing. Oxygen consumption (VO_2) is determined by the following definition:

$$VO_2 = \frac{\text{Volume of expired air (L)}_{STPD}}{\text{Min.}} \times \frac{\text{True Oxygen}}{100}$$

where True Oxygen (%) is:

$$(\%\ N_2 \text{ exhaled air} \times \frac{O_2 \text{ (atm. air)}}{N_2 \text{ (atm. air)}}) - \%\ O_2 \text{ exhaled air}$$

G. Blood Collection Procedure

Non-fasting blood samples were drawn three times during the exercise protocol on Days 8, 10, 20, 22 and 32. All blood samples were drawn from the antecubital vein. In

addition fasting blood samples were drawn on Days 1, 9, 21 and 33.

G.1.a. Non-fasting Blood Samples. One 15 ml. BD Vacutainer Tube (No. 4796) of blood was drawn from each subject one minute before the end of the rest period, within thirty seconds of the cessation of the exercise period and again twenty minutes later. The blood samples obtained during the exercise protocol were analysed for the metabolites, glucose, glycerol, lactate and pyruvate.

Two ml. of whole blood was removed with a pipette from each 15 ml. sample within thirty seconds of collecting the sample and added to 5 ml. 8% perchloric acid. The mixture was shaken and put on an ice bath for five minutes. The sample was then centrifuged for ten minutes at 1,400 x g. The protein-free filtrate obtained was used for lactate and and pyruvate determinations. The samples were stored at refrigerator temperature overnight and chemical analyses were carried out the following day (H.1.a.). The remaining 13 ml. of whole blood was divided into two centrifuge tubes. The blood samples were allowed to clot for approximately fifteen minutes and then centrifuged at 1,400 x g. for ten minutes. The serum was removed from each tube and stored in vials for glucose and glycerol determinations. The glycerol determination was done immediately (H.2.b.). The serum for glucose determination was stored at refrigerator temperature overnight and chemical analysis was carried out

the following day (H.2.a.). All samples were analysed in duplicate.

G.1.b. Fasting Blood Samples. Subjects were instructed to have nothing to eat or drink except water after midnight prior to taking blood samples. Three samples of blood were drawn on each collection day from each of the subjects. One 7 ml. sample taken in a BD Vacutainer Tube (No. 4759)[13] treated with EDTA was sent to the Health Sciences Centre hematology laboratory for whole blood hematology. The blood samples were refrigerated prior to sending them to the laboratory. One 10 ml. blood sample taken in a BD Vacutainer Tuber (No. 4710)[13] was obtained for serum lipid analysis. The blood samples were treated as described by Huisman (1974). Sera from each subject were analysed for total cholesterol, triglycerides and lipid phosphorus content (H.2.c,d,e). The third blood sample collected in a 15 ml. BD Vacutainer Tube (No. 4796)[13] was used for glucose, glycerol, lactate and pyruvate determinations. The blood samples were treated as described in G.1.a. All samples were analysed in duplicate.

H. Chemical Analyses of Blood

H.1. Whole Blood

Whole blood samples were analysed for leukocytes, total red blood cell count, platelets, reticulocytes,

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[13]Canlab Laboratory Equipment, Winnipeg, Manitoba.

hematocrit, haemoglobin, lactate and pyruvate content. With the exception of lactate and pyruvate determinations all analyses on whole blood were done by the Health Sciences Centre Hematology Laboratory.

H.1.a. Venous Lactate and Pyruvate. The lactate and pyruvate content of the whole blood samples were determined as described in Sigma Technical Bulletin 726/826-UV-10-68.[14]

H.2. Serum.

Serum samples were analysed for glucose, glycerol, cholesterol, triglyceride and lipid phosphorus.

H.2.a. Glucose. Serum glucose determinations were carried out as described in Sigma Technical Bulletin 510-5-69.[15] The procedure described in the bulletin is a modification of the Raabo and Terkildsen (1960) procedure.

H.2.b. Glycerol. The enzymic assay of serum glycerol was determined as described in the Triglyceride Reagent set from Worthington Biochemical Corporation.[16] The procedure is that of Pinter et al. (1967).

H.2.c. Total Cholesterol. Total serum cholesterol was determined by the method described by Pearson et al. (1952; 1953). Samples were compared to a standard of known

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[14]Sigma Chemical Company, P.O. Box 14508, St. Louis, Missouri, 63178, U.S.A.

[15]Sigma Chemical Co., 3500 Dekalb St., St. Louis, Missouri, 63118, U.S.A.

[16]Worthington Biochemical Corporation, Freehold, New Jersey, 07728.

cholesterol content.

H.2.d. Triglycerides. The extraction procedure was carried out as described by Ryan and Rasho (1967), while the saponification and colour reactions were determined as described by Van Handel and Zilversmit (1957) and Van Handel (1961). Further modifications included the use of sodium bisulfite instead of sodium arsenite as suggested by Jagannathan (1964). Absolute alcohol was used for saponification of serum blanks. Tripalmitin[17] was used as a standard. Pure chromatidic acid was used as a blank.

H.2.e. Lipid Phosphorus. Extraction of the lipid from the serum was carried out as described by Fiske and Subbarow (1925). Ashing and colourmetric determinations were carried out as described by Chen et al. (1956) with a slight modification made in our laboratory. In charring, immediately after evaporation of the filtrate, the sides of the test tubes were washed with 0.5 ml. alcohol-ether solvent. Samples were compared to standards of known phosphorus content.

I. Statistical Analysis

All data were subjected to analysis of variance of a 2-way classification for a completely randomized block design according to Snedecor and Cochran (1967). The sum

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[17]Honmel Institute, Lipids Preparation Laboratory, 801-16th Ave., N.E., Austin, Minnesota 55912.

of squares attributed to days was partitioned in order to make appropriate orthogonal comparison to determine significant differences between diets.

RESULTS AND DISCUSSION

A. Physical Health of the Subjects

The four male subjects participating in the study remained in good health throughout the 32-day metabolic study. Body weights for the subjects remained constant throughout the experiment (Table 5). No dietary upsets were reported by the subjects fed diets containing 126 grams of soybean oil or canbra oil daily. Other studies in the Department of Foods and Nutrition, University of Manitoba, using canbra oil (LeBlanc, 1973) and rapeseed oil (Huisman, 1974) also did not encounter any dietary upsets specifically related to the type of oil fed in a mixed diet. However Trémolières et al. (1971) reported dietary upsets when human subjects were given approximately 30 ml. of liquid rapeseed oil in a single dose on an empty stomach.

B. Analysis of Diets

The mixed fat, soybean oil and canbra oil diets were all reasonably well accepted. Acceptability problems were encountered with the Sweet and Sour Pork entree on all three diets. The problem was subsequently found to be due to the inadequate incorporation of the fat into the corn starch used.

The solid test diet used in this study was similar to that used by Ravensdale (1972), Le Blanc (1973) and

Huisman (1974). The diet fed during the stabilization period was the same as that fed during the experimental periods, except that either soybean oil or canbra oil were the sole source of added fat during the experimental periods. Unlike the solid test diets used by Goldsmith et al. (1960), Eneroth et al. (1964), and Moore et al. (1968) which provided only 70-88 per cent of fat calories from the fat sources studied, the present diet derived approximately 95 per cent of fat calories from the fats being studied. A solid test diet was used in the present study because liquid formula test diets have been found to produce alterations in serum lipid levels unrelated to the fat contained in the formulae (Anderson et al., 1961).

Flatulence, a problem which had been previously encountered with diets similar to the one used in the present study (Ravensdale, 1972; Le Blanc, 1973; Huisman, 1974) was not a problem in the present study. Absence of this problem in the present study probably relates to the fact that TVP was reduced from 93 to 25 grams daily.

The mixed fat, soybean and canbra oil diets differed in the ratio of saturated to unsaturated fatty acids (Table 14). The ratios in the soybean and canbra oil diets were 1.0:4.6 and 1.0:6.8, respectively. The mixed fat diet was appreciably lower in unsaturated fatty acids than the experimental diets, thus the ratio of saturated to unsaturated was only 1.0:1.8. The predominant fatty acid in the experimental diets were oleic and linoleic; accounting for 75-80 per cent of the

total fatty acids. In the canbra oil diet oleic and linoleic made up 65 and 14 per cent of the fatty acids respectively, whereas in the soybean oil diet they made up 44 and 33 per cent, respectively. The soybean and canbra oil diets were similar in stearic acid and linolenic acid content (Table 14). The canbra oil diet unlike the mixed fat and soybean oil diets, contained low levels of eicosenoic and erucic acids (Table 14). Crisco oil, the pure soybean oil, purchased on the local market was partially hydrogenated. This was evident by the substantially lower levels of linoleic and linolenic acids and the higher level of oleic acid in contrast to the composition of soybean oil reported by Craig (1970) (Table 1).

C. Energy Metabolism

C.1. Ventilation Rate

Pulmonary ventilation is the mass movement of gas in and out of the lungs and is regulated so as to provide the gaseous exchange required for aerobic energy metabolism. The number of liters of gas exhaled per minute describes the ventilation rate. The initial increase in ventilation rate at the commencement of exercise is affected by one or more factors such as nervous regulation, total muscle effort, etc.

During exercise ventilation rates increased substantially (25-31 liters/min.) on all three diets (Tables 18 and 19 and Figure 2). Ventilation rates decreased during the recovery period, but the mean recovery ventilation rates were higher than the resting values. No significant difference

Table 18

Ventilation Rates Observed
During the Experiment

Subjects		Days of Experiment[1] 8	10	20	22	32
		liters/minute				
1. H.R.	Re.	6.23[2]	5.48	5.72	5.24	6.41
	Ex.	36.15[2]	37.22	36.79	34.87	34.32
	Rec.	9.98[2]	9.20	9.73	9.14	9.69
2. G.C.	Re.	7.37	8.17	7.39	5.23	7.17
	Ex.	35.98	31.19	38.02	34.79	35.29
	Rec.	11.05	9.86	10.75	9.13	10.02
3. T.T.	Re.	8.36	7.55	7.28	7.76	7.48
	Ex.	40.52	38.17	40.33	39.61	41.73
	Rec.	11.76	10.44	10.73	9.89	11.44
4. S.M.	Re.	7.94	7.68	7.05	7.22	8.45
	Ex.	42.48	41.99	43.21	43.44	44.00
	Rec.	11.25	11.29	11.52	12.14	12.52

[1]Experimental protocol: Days 1 to 8 - all subjects Mixed Fat; Days 10 to 20 - Subjects H.R. and G.C. soybean oil diet, T.T. and S.M. canbra oil diet; Days 21 to 32 - subjects H.R. and G.C. canbra oil diet, T.T. and S.M. soybean oil diet.

[2]Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition. Iowa State University Press, Ames, Iowa. p.317.

Table 19

Ventilation Rates Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[1]

Subjects		Mixed Fat	Soybean Oil	Canbra Oil
		liters/minute		
1. H.R.	Re.	6.23	5.72	6.41
	Ex.	36.15	36.79	34.32
	Rec.	9.98	9.73	9.69
2. G.C.	Re.	7.37	7.39	7.17
	Ex.	35.98	38.02	35.29
	Rec.	11.05	10.75	10.02
3. T.T.	Re.	8.36	7.48	7.28
	Ex.	40.52	41.73	40.33
	Rec.	11.76	11.44	10.73
4. S.M.	Re.	7.94	8.45	7.05
	Ex.	42.48	44.00	43.21
	Rec.	11.25	12.52	11.52
Group Mean (N = 4)	Re.	7.48	7.26	6.98
	Ex.	38.78	40.14	38.29
	Rec.	11.01	11.11	10.49
SD ±	Re.	0.92	1.13	0.40
	Ex.	3.24	3.32	4.21
	Rec.	0.75	1.17	0.81

[1]After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

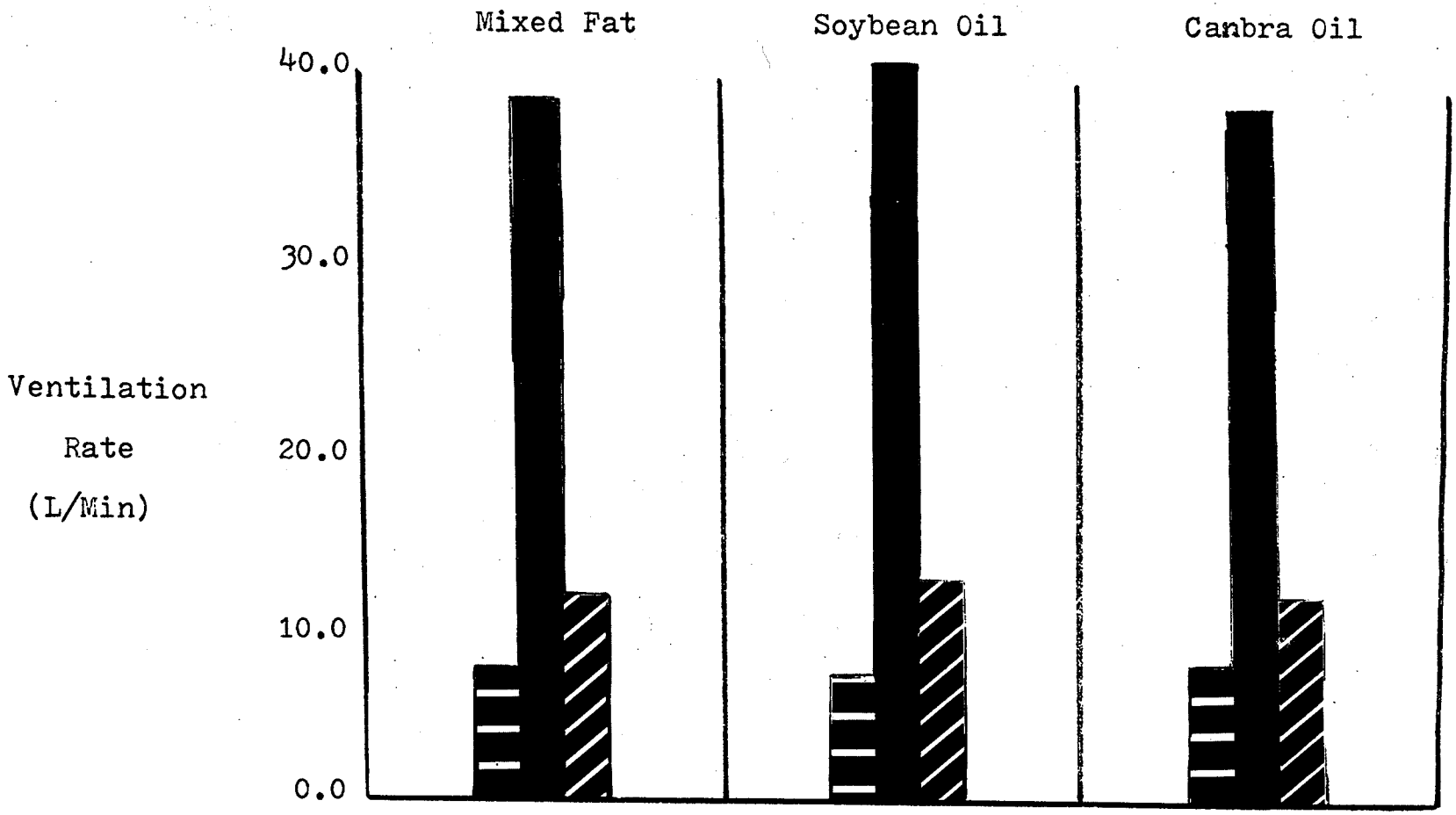

Figure 2. Mean Ventilation Rates During Rest, Exercise and Recovery.

(α=.01) was observed in ventilation rate between the soybean and canbra oil diets (Appendix Table 18). The observation that ventilation rates increased during exercise and decreased during recovery on all three diets indicated that changes in ventilation rates were the result of work intensity and not due to dietary regimen. This observation coincided with the observation of Craig and Cummings (1960) and Craig et al. (1963) that ventilation rate was proportional to work intensity.

C.2. Oxygen Consumption

The energy expenditure of physical activity frequently is described in terms of the amount of oxygen consumed per unit time (liters/min.). Oxygen consumption during physical activity increases at the onset of the activity and reaches a plateau at the point where oxygen uptake reaches a maximal. A similar pattern is observed in pulse and heart rates as the organism adjusts to the physical activity (Astrand, 1960). The greater the oxygen uptake the greater the energy output.

Exercise oxygen consumption was substantially higher (1.8 - 2.0 LO_2/min.) than resting oxygen consumption on all three diets (Tables 20 and 21 and Figure 3). During the recovery period the oxygen consumption decreased but the mean value over this period was substantially higher than the mean oxygen consumption during the resting period. However no significant difference in oxygen uptake was observed between the soybean and canbra oil diets (Appendix

Table 20

Oxygen Consumption Observed
During the Experiment

Subjects		Days of Experiment[1]				
		8	10	20	22	32
		liters oxygen/minute				
1. H.R.	Re.	0.39[2]	0.24	0.24	0.28	0.64
	Ex.	2.39[2]	2.02	2.03	2.01	3.43
	Rec.	0.59[2]	0.42	0.44	0.48	0.97
2. G.C.	Re.	0.30	0.35	0.30	0.21	0.31
	Ex.	1.94	1.75	2.02	1.77	1.89
	Rec.	0.41	0.41	0.45	0.36	0.40
3. T.T.	Re.	0.36	0.33	0.30	0.33	0.28
	Ex.	2.09	1.97	2.00	1.94	2.07
	Rec.	0.51	0.43	0.45	0.39	0.47
4. S.M.	Re.	0.36	0.36	0.30	0.33	0.36
	Ex.	2.06	2.31	2.12	2.14	2.16
	Rec.	0.46	0.48	0.47	0.46	0.51

[1] Experimental protocol: Days 1 to 8 - all subjects Mixed Fat; Days 10 to 20 - Subjects H.R. and G.C. soybean oil diet, T.T. and S.M. canbra oil diet; Days 21 to 32 - subjects H.R. and G.C. canbra oil diet, T.T. and S.M. soybean oil diet.

[2] Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition. Iowa State University Press, Ames, Iowa. p.317.

Table 21

Oxygen Consumption Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[1]

Subjects		Mixed Fat	Soybean Oil	Canbra Oil
		liters Oxygen/minute		
1. H.R.	Re.	0.39	0.24	0.64
	Ex.	2.39	2.03	1.99
	Rec.	0.59	0.44	0.97
2. G.C.	Re.	0.30	0.30	0.31
	Ex.	1.94	2.02	1.89
	Rec.	0.41	0.45	0.40
3. T.T.	Re.	0.36	0.28	0.30
	Ex.	2.09	2.07	2.00
	Rec.	0.51	0.47	0.45
4. S.M.	Re.	0.36	0.36	0.30
	Ex.	2.06	2.16	2.12
	Rec.	0.46	0.51	0.47
Group Mean (N = 4)	Re.	0.35	0.30	0.36
	Ex.	2.12	2.07	2.00
	Rec.	0.49	0.47	0.57
SD ±	Re.	0.04	0.05	0.17
	Ex.	0.19	0.06	0.09
	Rec.	0.08	0.03	0.27

[1] After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

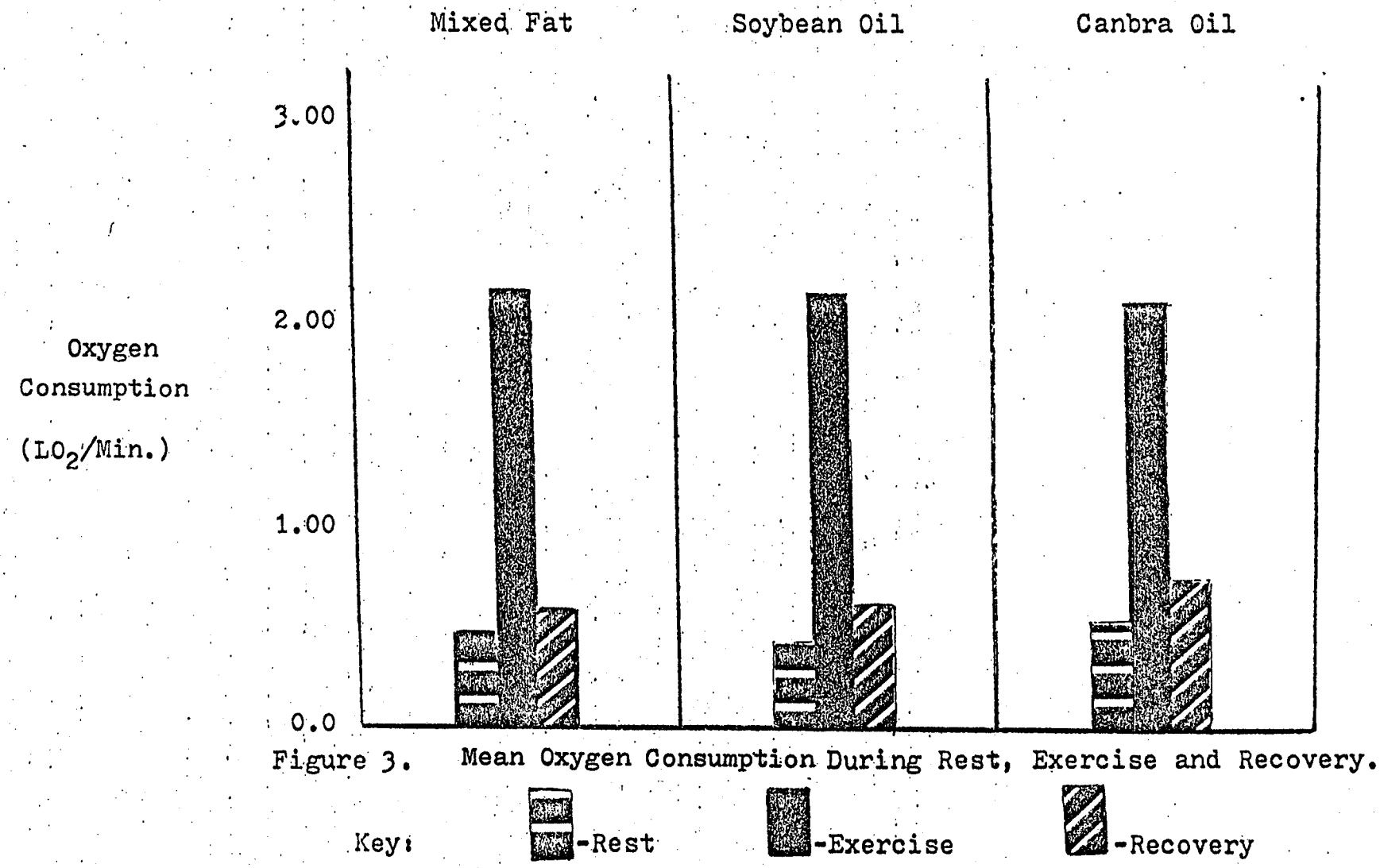

Figure 3. Mean Oxygen Consumption During Rest, Exercise and Recovery.

Table 19). Neither soybean oil or canbra oil had any effect on oxygen consumption during physical work when compared with the mixed fat diet. This was in contrast to the observation of Tremolieres et al. (1971) who found that the ingestion of a single dose of high erucic acid rapeseed oil, when compared to peanut oil, surpressed oxygen consumption. Tremolieres et al. (1971) reports that the depression in oxygen consumption was not significant.

C.3. Respiratory Quotient

It is now clearly established that fat is an important source of fuel for the working muscle, and that the percentage participation of fat and carbohydrate depend on a number of factors such as intensity and duration of work (Astrand, 1967), diet (Issekutz et al., 1963) and physical fitness (Havel et al., 1963, 1964).

Respiratory Quotient (RQ), the ratio of the volume of carbon dioxide produced to the volume of oxygen utilized, can be used to assess the foodstuff being oxidized during

energy metabolism. Theoretically if the foodstuff being oxidized is carbohydrate (glucose) the RQ would be 1.0, however if pure triglycerides were being oxidized the RQ would be lower (0.58). Thus RQ can be used to estimate the participation of carbohydrate and fat in energy metabolism.

Resting RQs on the mixed fat, soybean and canbra oil diets were 0.78, 0.80 and 0.79 respectively (Tables 22 and 23 and Figure 4). Resting RQs indicated that between 68-75% of the energy utilized came from fat. During exercise the contribution of fat as a source of muscle energy decreased to 21-31%. Exercise RQs on the mixed fat, soybean and canbra oil diets were 0.91, 0.94 and 0.92, respectively. However during the recovery period the contribution of fat increased again to 27-41% as indicated by recovery RQs of 0.92 for the mixed fat diet and 0.88 and 0.90 for the soybean and canbra oil diets, respectively. There was no significant difference (α=.01) in RQ between the soybean and the canbra oil diets (Appendix Table 20). During the mixed fat and experimental periods exercise RQs were slightly higher than resting RQs, but both the resting and exercise RQs were similar on all three diets. RQs following an overnight fast were not different from RQs during rest measured 2.5 hours post-prandial.

Trémolières et al. (1971) observed a pronounced lowering of RQ at rest, with an additional decrease in RQ during muscular exercise when rapeseed oil was fed. On the basis of the lower RQs during rest Trémolières et al. (1971)

Table 22

Respiratory Quotients Observed
During the Experiment

Subjects		Days of Experiment[1] 8	10	20	22	32
1. H.R.	Fasting	ND	ND	ND	0.84	0.81
	Re.	0.78[2]	0.87	0.79	0.79	0.79
	Ex.	0.94[2]	0.97	0.98	0.93	0.93
	Rec.	0.93[2]	0.95	0.88	0.94	0.91
2. G.C.	Fasting	ND	ND	ND	0.94	0.80
	Re.	0.78	0.77	0.80	0.82	0.80
	Ex.	0.87	0.88	0.92	0.94	0.89
	Rec.	0.94	1.01	0.91	0.89	0.90
3. T.T.	Fasting	ND	ND	ND	0.76	0.79
	Re.	0.71	0.81	0.77	0.82	0.79
	Ex.	0.87	0.90	0.92	0.92	0.90
	Rec.	0.87	0.90	0.87	0.90	0.87
4. S.M.	Fasting	ND	ND	ND	0.84	0.81
	Re.	0.83	0.84	0.81	0.83	0.83
	Ex.	0.97	0.94	0.94	0.96	0.96
	Rec.	0.94	0.93	0.92	0.94	0.92

[1]Experimental protocol: Days 1 to 8 - all subjects Mixed Fat; Days 10 to 20 - Subjects H.R. and G.C. soybean oil diet, T.T. and S.M. canbra oil diet; Days 21 to 32 - subjects H.R. and G.C. canbra oil diet; T.T. and S.M. soybean oil diet.

[2]Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition. Iowa State University Press, Ames, Iowa. p.317.

ND - not determined.

Table 23

Respiratory Quotients Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[1]

Subjects		Mixed Fat	Soybean Oil	Canbra Oil
1. H.R.	Fasting	ND	ND	0.81
	Re.	0.78	0.79	0.79
	Ex.	0.94	0.98	0.93
	Rec.	0.93	0.88	0.91
2. G.C.	Fasting	ND	ND	0.80
	Re.	0.78	0.80	0.80
	Ex.	0.87	0.92	0.89
	Rec.	0.94	0.91	0.90
3. T.T.	Fasting	ND	0.79	ND
	Re.	0.71	0.79	0.77
	Ex.	0.87	0.90	0.92
	Rec.	0.87	0.87	0.87
4. S.M.	Fasting	ND	0.81	ND
	Re.	0.83	0.83	0.81
	Ex.	0.97	0.96	0.94
	Rec.	0.94	0.92	0.92
Group Mean	Fasting	ND	0.80	0.81
	Re.	0.78	0.80	0.79
	Ex.	0.91	0.94	0.92
	Rec.	0.92	0.88	0.90
SD ±	Re.	0.05	0.02	0.02
	Ex.	0.05	0.04	0.02
	Rec.	0.03	0.02	0.02

[1] After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

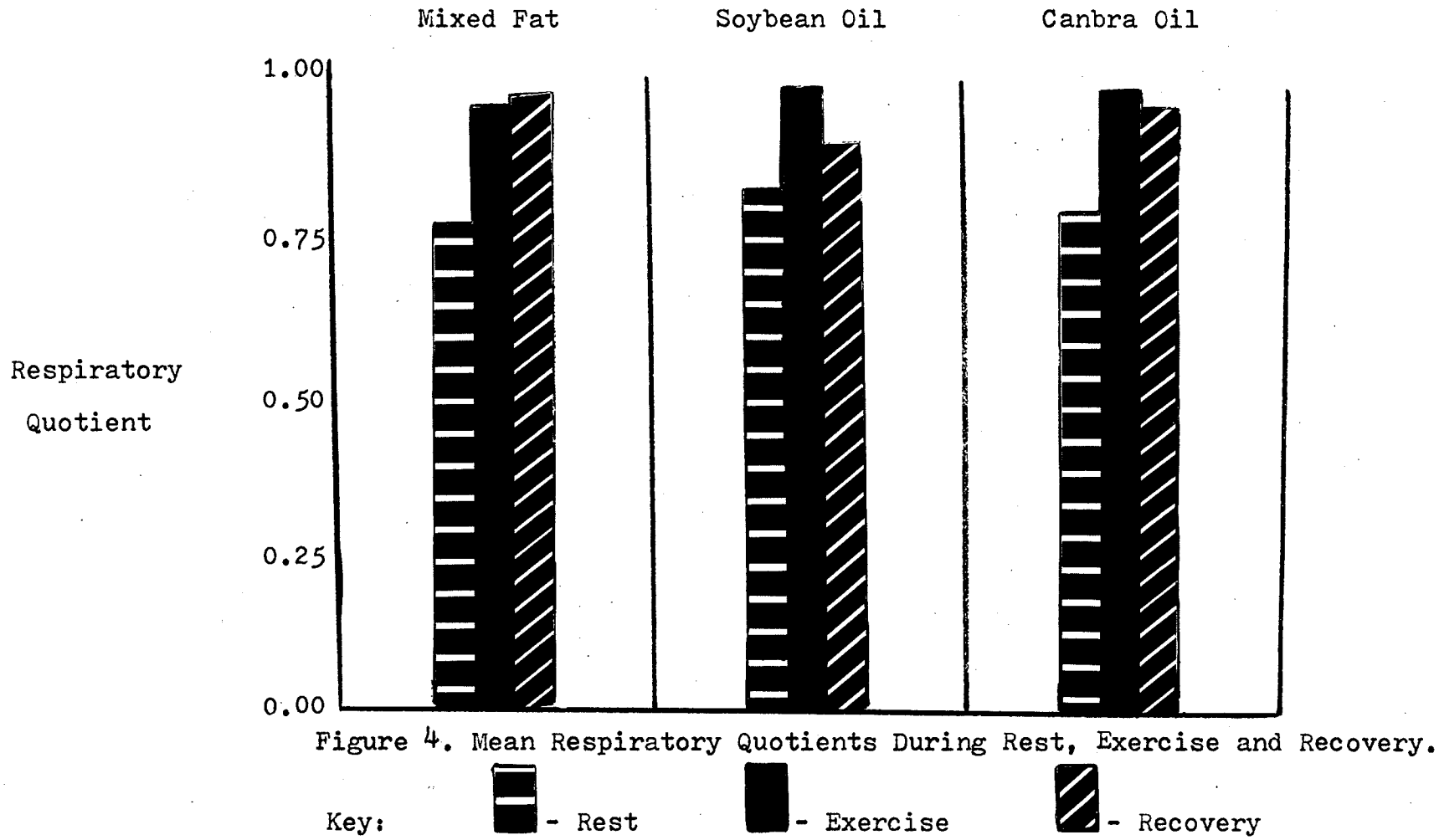

Figure 4. Mean Respiratory Quotients During Rest, Exercise and Recovery.

concluded that the fatty acids of rapeseed oil were preferentially oxidized during rest, with increased metabolism of carbohydrate occurring during exercise. In the present study on all three diets, exercise RQs were higher than resting RQs. On the basis of RQs observed during the rest and exercise periods in the present study (in contrast to the observations of the Trémolières study) there was no indication of preferential oxidation of fatty acid of either soybean or canbra oil at rest or during exercise.

D. Effect of Exercise on Specific Blood Parameters

D.1. Glucose

Unlike nervous tissues, peripheral muscles use only small amounts of glucose as an energy source unless stimulated by insulin or exercise. The increased rate of oxygen consumption and carbon dioxide production accompanying muscular work increases the withdrawal of glucose from the plasma by peripheral muscles (Reichard et al., 1961).

Resting serum glucose for the mixed fat diet was substantially higher than on either the soybean or canbra oil diets. This observation was consistent for three subjects (Tables 24 and 25, and Figure 5). During exercise serum glucose decreased appreciably on all three diets (15-33 mg/100 ml., Table 25). The mean decrease in serum glucose during exercise was identical for the soybean and canbra oil diets (15 mg/100 ml.), but was substantially less than that observed on the mixed fat diet (33 mg/100 ml.). Serum

Table 24

Blood Glucose Concentrations Observed During the Experiment

Subjects		Days of Experiment[1] 8	10	20	22	32
		mg glucose/100 ml.				
1. H.R.	Re.	119[2]	97	104	91	90
	Ex.	88[2]	82	85	75	80
	Rec.	78[2]	79	83	78	80
2. G.C.	Re.	118	92	101	97	96
	Ex.	83	70	72	84	65
	Rec.	83	82	74	91	70
3. T.T.	Re.	123	89	80	77	89
	Ex.	72	59	66	66	81
	Rec.	73	72	75	89	90
4. S.M.	Re.	106	105	94	89	96
	Ex.	92	82	87	75	93
	Rec.	80	84	90	69	82

[1]Experimental protocol: Days 1 to 8 - all subjects Mixed Fat; Days 10 to 20 - Subjects H.R. and G.C. soybean oil diet, T.T. and S.M. canbra oil diet; Days 21 to 32 - Subjects H.R. and G.C. canbra oil diet, T.T. and S.M. soybean oil diet.

[2]Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition. Iowa State University Press, Ames, Iowa. p.317.

Table 25

Blood Glucose Concentrations Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[1]

Subjects		Mixed Fat	Soybean Oil	Canbra Oil
		mg glucose/100 ml.		
1. H.R.	Re.	119	104	90
	Ex.	88	85	80
	Rec.	78	83	80
2. G.C.	Re.	118	101	96
	Ex.	83	72	65
	Rec.	83	74	70
3. T.T.	Re.	123	89	80
	Ex.	72	81	66
	Rec.	73	90	75
4. S.M.	Re.	106	96	94
	Ex.	92	93	87
	Rec.	80	82	90
Group Mean (n = 4)	Re.	117	98	90
	Ex.	84	83	75
	Rec.	79	82	79
SD ±	Re.	7.3	6.6	7.1
	Ex.	8.7	8.7	10.8
	Rec.	4.2	6.6	8.5

[1] After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

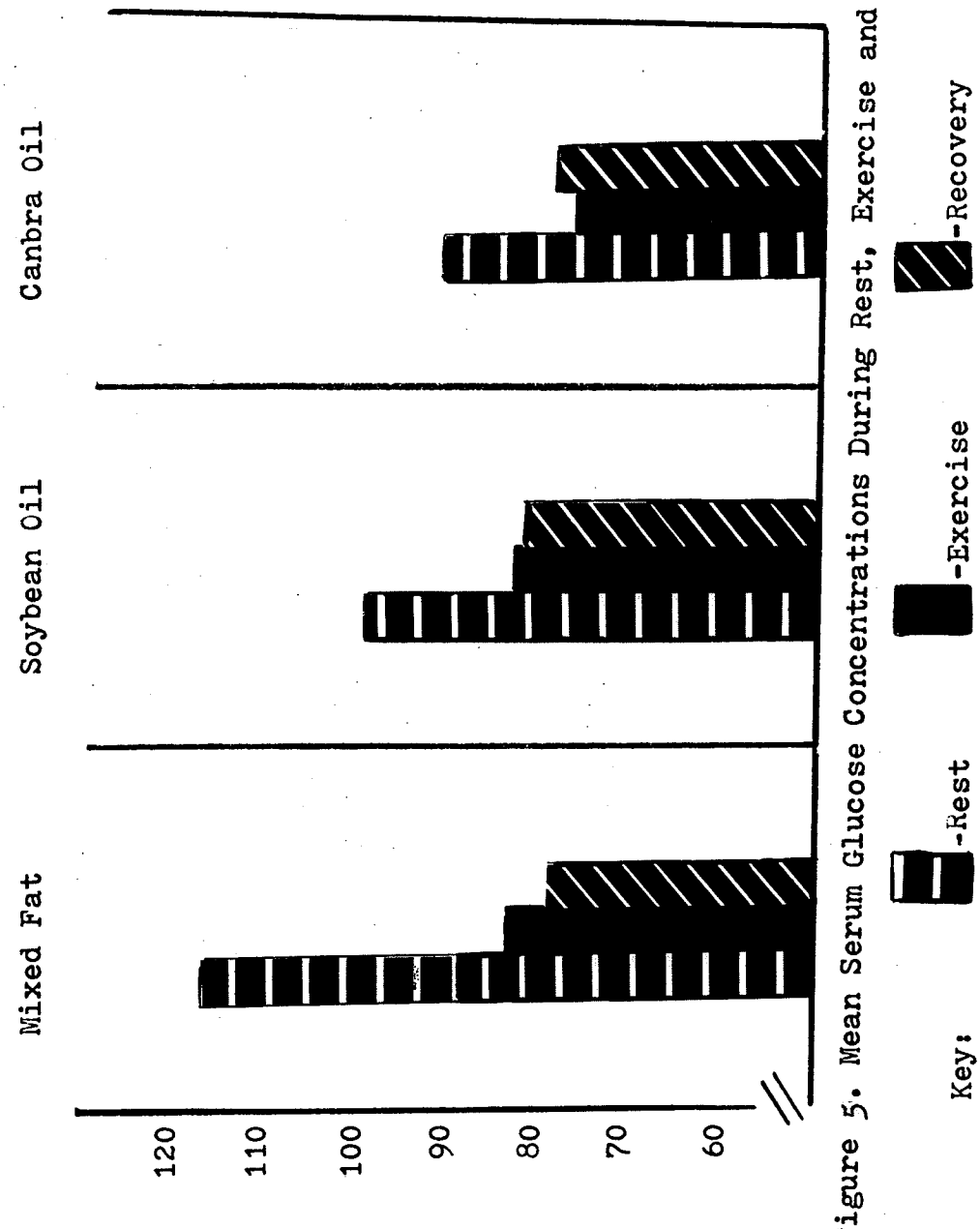

Figure 5. Mean Serum Glucose Concentrations During Rest, Exercise and Recovery.

glucose continued to decrease slightly (5 mg/100 ml.) on the mixed fat diet during the recovery period, however there was a slight increase (4 mg/100 ml.) for the canbra oil diet, and no change on the soybean oil diet. Thus there was no significant difference (α=.01) in serum glucose between the soybean and canbra oil diets (Appendix Table 21). Decreased serum glucose during exercise and a concomitant increase in free fatty acids has been reported (Young et al., 1966).

D.2. Lactate, Pyruvate and Lactate/Pyruvate Ratios

During physical activity lactate and pyruvate concentrations in the blood increase indicating an anaerobic condition in the working muscle. However lactate is known to increase in conditions where hypoxia was absent. Thus the ratio of lactate to pyruvate has been suggested (Harris et al., 1962) as a better index of cellular oxygenation than lactate alone. Indirectly the ratio also reflects the oxidation-reduction potential of the tissue (Harris et al., 1962). As pyruvate is reduced to lactate in the presence of lactic dehydrogenase, diphosphopyridine nucleotide is simultaneously converted from the reduced to the oxidized form. Thus the ratio of the concentrations of lactate to pyruvate is, in the presence of a constant concentration of hydrogen ions, proportional to the ratio of the concentrations of the reduced to oxidized form of diphosphopyridine nucleotide.

Plasma lactate concentrations increased substantially (295-374 μmole/100 ml.) during exercise for all three dietary

fat sources (Tables 26 and 27 and Figure 6). Lactate concentrations decreased during the recovery period, however the mean values were slightly higher than the resting values. Plasma lactate concentrations for the canbra oil diet were not significantly different (α=.01) (Appendix Table 22) from plasma lactate concentrations on the soybean oil diet although mean values (Table 27) were somewhat lower on the canbra diet. In the present study plasma lactate concentrations at rest and during recovery for all three diets were higher than those observed by Trémolières et al., (1971). The higher values obtained in the present study are probably attributable to the higher work load (950 kpm) used in this study.

Plasma pyruvate concentrations increased during the exercise period (9-12 μmoles/100 ml.) (Tables 28 and 29, and Figure 7) and decreased during the recovery period, although the mean values were higher than the resting values, on all three diets. Pyruvate concentrations did not differ significantly (α=.01) between the soybean and canbra oil diets (Appendix Table 23). In the present study pyruvate concentrations like lactate concentrations were higher than those observed by Trémolières et al. (1971).

Lactate/pyruvate ratios increased (9-15) during exercise for all three diets and then decreased during the recovery periods (Tables 30 and 31 and Figure 8). Lactate/pyruvate ratios were not significantly different (α=.01) for the experiment diets (Appendix Table 24). The close similarity

Table 26

Plasma Lactate Concentrations Observed During the Experiment

Subjects		Days of Experiment[1] 8	10	20	22	32
		μmoles/100 ml. whole blood				
1. H.R.	Re.	155.4 [2]	84.4	86.9	99.5	88.0
	Ex.	617.1 [2]	545.0	594.3	439.4	404.7
	Rec.	272.0 [2]	313.0	298.5	230.8	165.7
2. G.C.	Re.	95.8	96.6	69.0	96.7	76.2
	Ex.	349.8	303.0	279.4	278.4	254.6
	Rec.	161.6	106.6	150.3	127.1	107.7
3. T.T.	Re.	237.8	74.4	46.3	68.4	60.3
	Ex.	474.4	236.4	312.8	310.9	327.5
	Rec.	135.1	96.6	105.5	102.3	101.2
4. S.M.	Re.	109.7	99.9	84.7	107.8	104.0
	Ex.	652.2	495.1	503.1	594.0	554.8
	Rec.	208.9	190.9	218.0	248.6	227.3

[1] Experimental protocol: Days 1 to 8 - all subjects Mixed Fat; Days 10 to 20 - Subjects H.R. and G.C. soybean oil diet, T.T. and S.M. canbra oil diet; Days 21 to 32 - subjects H.R. and G.C. canbra oil diet, T.T. and S.M. soybean oil diet.

[2] Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition. Iowa State University Press, Ames, Iowa. p.317.

Table 27

Plasma Lactate Concentrations Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[1]

Subjects		Mixed Fat	Soybean Oil	Canbra Oil
		μ moles/100 ml. whole blood		
1. H.R.	Re.	155.4	86.9	88.0
	Ex.	617.1	594.3	404.7
	Rec.	272.0	298.5	165.7
2. G.C.	Re.	95.8	69.0	76.2
	Ex.	349.8	279.4	254.6
	Rec.	161.6	150.3	107.7
3. T.T.	Re.	237.8	60.3	46.3
	Ex.	474.4	327.5	312.8
	Rec.	135.1	101.2	105.5
4. S.M.	Re.	109.7	104.0	84.7
	Ex.	652.2	554.8	503.1
	Rec.	208.9	227.3	218.0
Group Mean (N = 4)	Re.	149.7	80.1	73.8
	Ex.	523.4	439.0	368.8
	Rec.	194.4	194.3	149.2
SD ±	Re.	64.0	19.4	19.0
	Ex.	139.0	158.6	108.8
	Rec.	60.1	86.7	53.7

[1] After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

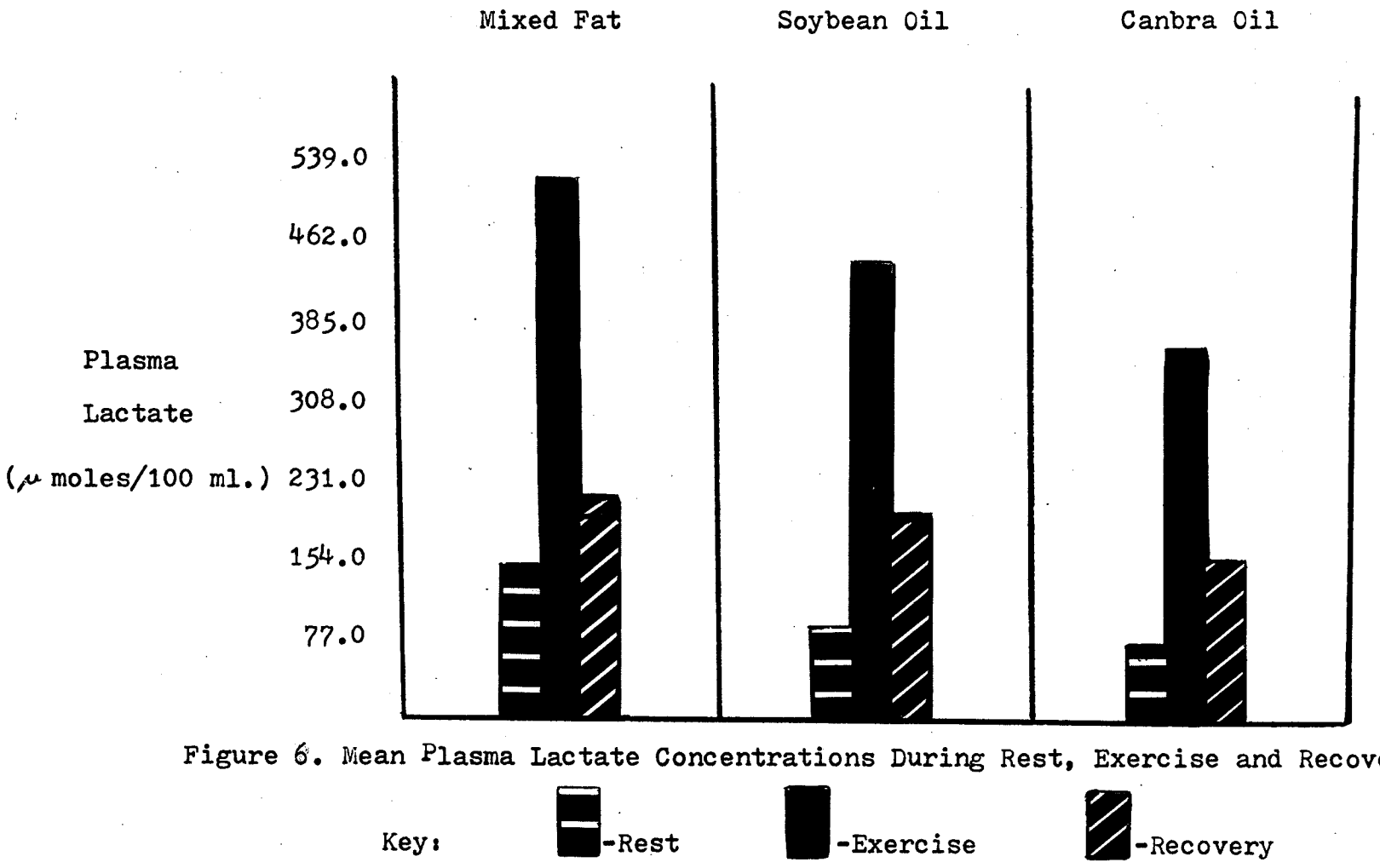

Figure 6. Mean Plasma Lactate Concentrations During Rest, Exercise and Recovery.

Table 28

Plasma Pyruvate Concentrations
Observed During the Experiment

Subjects		Days of Experiment[1]				
		8	10	20	22	32
		μmoles/100 ml. whole blood				
1. H.R.	Re.	11.5[2]	7.5	9.2	7.8	7.0
	Ex.	26.4[2]	20.5	24.2	18.7	17.0
	Rec.	19.5[2]	17.8	18.9	15.7	12.0
2. G.C.	Re.	5.8	5.3	8.8	7.2	5.0
	Ex.	21.2	13.2	13.1	12.04	10.3
	Rec.	11.5	7.5	8.9	9.1	5.0
3. T.T.	Re.	16.4	7.0	5.2	4.9	4.2
	Ex.	20.6	14.0	14.5	14.9	12.0
	Rec.	14.7	7.3	10.3	6.1	6.3
4. S.M.	Re.	7.6	7.2	7.7	8.2	7.8
	Ex.	21.6	19.9	18.9	20.0	16.8
	Rec.	15.5	14.8	16.7	16.4	14.9

[1]Experimental protocol: Days 1 to 8 - all subjects Mixed Fat; Days 10 to 20 - Subjects H.R. and G.C. soybean oil diet, T.T. and S.M. canbra oil diet; Days 21 to 32 - subjects H.R. and G.C. canbra oil diet, T.T. and S.M. soybean oil diet.

[2]Calculated value according to Snedecor, G.W. and Cochran, W.G., 1967. Statistical Methods, 6th Edition. Iowa State University Press, Ames, Iowa. p.317.

Table 29

Plasma Pyruvate Concentrations Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[1]

Subjects		Mixed Fat	Soybean Oil	Canbra Oil
		μ moles/100 ml. whole blood		
1. H.R.	Re.	11.5	9.2	7.0
	Ex.	26.4	24.2	17.0
	Rec.	19.5	18.9	12.0
2. G.C.	Re.	5.8	8.8	5.0
	Ex.	21.1	13.1	10.3
	Rec.	11.5	8.9	5.0
3. T.T.	Re.	16.4	4.2	5.2
	Ex.	20.6	12.0	14.5
	Rec.	14.7	6.3	10.3
4. S.M.	Re.	7.6	7.8	7.7
	Ex.	21.6	16.8	18.9
	Rec.	15.5	14.9	16.7
Group Mean (N = 4)	Re.	10.3	7.5	6.3
	Ex.	22.4	16.5	15.2
	Rec.	15.3	12.2	11.0
SD ±	Re.	4.7	2.3	1.3
	Ex.	2.7	5.5	3.7
	Rec.	3.3	5.7	4.8

[1]After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

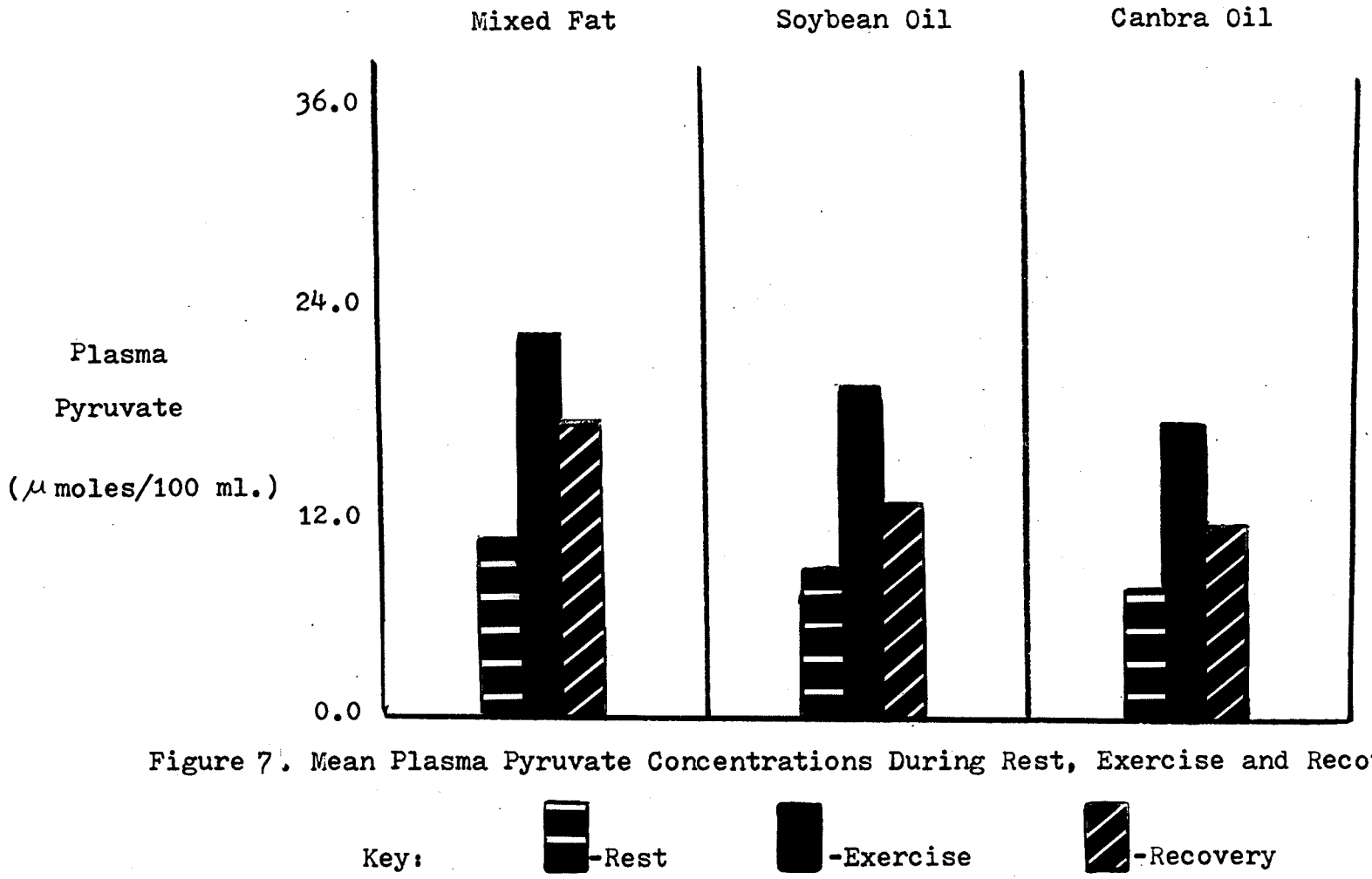

Figure 7. Mean Plasma Pyruvate Concentrations During Rest, Exercise and Recovery.

Table 30

Lactate/Pyruvate Ratios Observed During the Experiment

Subjects		Days of Experiment[1] 8	10	20	22	32
1. H.R.	Re.	13.6	11.3	9.5	12.7	12.5
	Ex.	23.4	26.7	24.6	23.4	23.8
	Rec.	13.9	17.6	15.8	14.7	13.8
2. G.C.	Re.	16.5	18.4	7.9	13.5	15.2
	Ex.	16.6	23.0	21.4	23.1	24.6
	Rec.	14.1	14.2	16.9	14.0	21.5
3. T.T.	Re.	14.5	10.6	8.9	14.0	14.4
	Ex.	23.1	16.9	21.5	20.9	27.2
	Rec.	9.2	13.3	10.2	16.7	16.2
4. S.M.	Re.	14.5	14.0	11.0	13.2	13.3
	Ex.	30.2	24.9	26.7	29.7	33.0
	Rec.	13.5	12.9	13.1	15.2	15.3

[1] Experimental protocol: Days 1 to 8 - all subjects Mixed Fat; Days 10 to 20 - Subjects H.R. and G.C. soybean oil diet, T.T. and S.M. canbra oil diet; Days 21 to 32 - Subjects H.R. and G.C. canbra oil diet, T.T. and S.M. soybean oil diet.

Table 31

Lactate/Pyruvate Ratios Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[1]

Subjects		Mixed Fat	Soybean Oil	Canbra Oil
1. H.R.	Re.	13.6	9.5	12.5
	Ex.	23.4	24.6	23.8
	Rec.	13.9	15.8	13.8
2. G.C.	Re.	16.5	7.9	15.2
	Ex.	16.6	21.4	24.6
	Rec.	14.1	16.9	21.5
3. T.T.	Re.	14.5	14.4	14.0
	Ex.	23.1	27.2	20.9
	Rec.	9.2	16.2	16.7
4. S.M.	Re.	14.5	13.3	13.2
	Ex.	30.2	33.0	29.7
	Rec.	13.5	15.3	15.2
Group Mean (N = 4)	Re.	14.8	11.2	13.7
	Ex.	23.3	26.5	24.8
	Rec.	12.7	16.1	16.8
SD ±	Re.	1.2	3.1	1.2
	Ex.	5.6	4.9	3.7
	Rec.	2.3	0.7	3.3

[1] After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

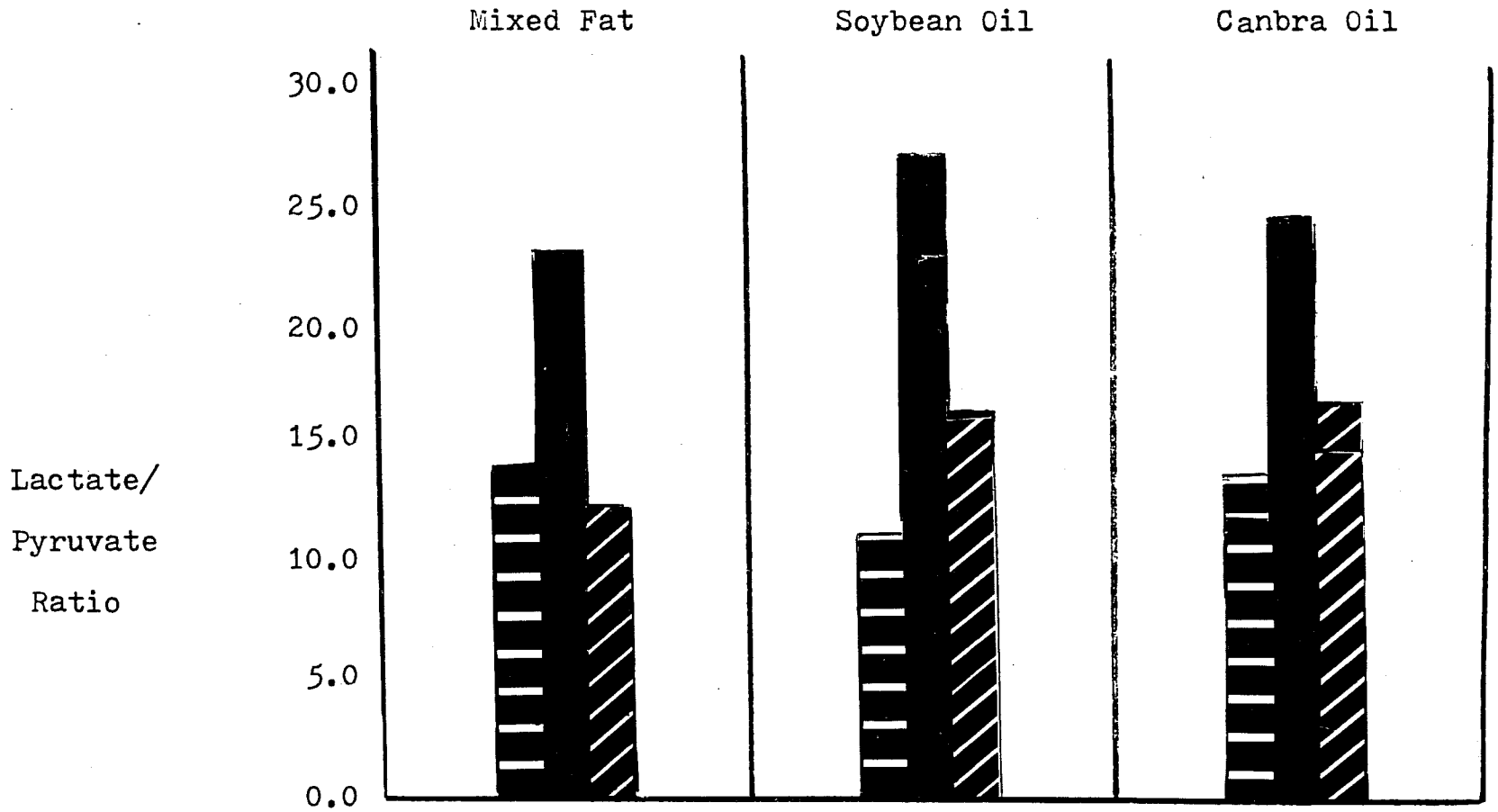

Figure 8. Mean Lactate/Pyruvate Ratios During Rest, Exercise and Recovery.

of the lactate/pyruvate ratios during exercise for all three fats indicated that muscular mitochondrial function was not altered when the soybean or canbra oil diets were substituted for the mixed fat diet. Trémolières et al. (1971) also found no alteration in muscular mitochondrial function in men fed a single dose of high erucic acid rapeseed oil. It is interesting to note that after 10 days of ingesting soybean oil or canbra oil no alteration was observed in mitochondrial function, although Houtsmuller et al. (1970) have suggested that it is at the mitochondrial level that rapeseed oil has its effect. However more recent work (Kramer et al., 1973) suggests that Houtsmuller et al. (1970) findings may have been confounded by improper mitochondrial isolation.

D.3. Glycerol

The release of free glycerol from the triglycerides of adipose tissues is influenced by conditions of fat mobilization. Unlike free fatty acids the glycerol moiety of the triglyceride can not be returned directly to the metabolic cycles of the adipose tissue, because apparently no pathway exists for the phosphorylation of glycerol in adipose tissue. Thus glycerol must be metabolized elsewhere in the body.

Three out of the four subjects exhibited a decrease in serum free glycerol concentration during exercise on the mixed fat diet (Tables 3_2 and 3_3 and Figure 9).

Table 32

Serum Free Glycerol Concentrations Observed During the Experiment

Subjects		Days of Experiment[1]				
		8	10	20	22	32
		mg/100 ml. free glycerol calculated as triglyceride				
1. H.R.	Re.	3.22[2]	2.49	1.47	2.58	1.98
	Ex.	2.44[2]	5.16	3.19	1.98	3.10
	Rec.	3.67[2]	3.96	4.47	3.01	2.06
2. G.C.	Re.	3.01	2.06	3.10	2.80	2.06
	Ex.	1.41[2]	2.49	3.44	2.33	2.07
	Rec.	2.32	2.92	3.18	2.58	2.33
3. T.T.	Re.	4.73	2.92	1.12	1.47	3.00
	Ex.	2.58	2.24	2.93	0.78	2.93
	Rec.	3.18	2.58	3.27	1.98	2.41
4. S.M.	Re.	2.83	3.27	3.10	2.06	2.24
	Ex.	3.78	4.39	3.78	3.53	3.27
	Rec.	3.96	4.56	2.75	2.93	2.84

[1]Experimental protocol: Days 1 to 8 - all subjects Mixed Fat; Days 10 to 20 - Subjects H.R. and G.C. soybean oil diet, T.T. and S.M. canbra oil diet; Days 21 to 32 - Subjects H.R. and G.C. canbra oil diet, T.T. and S.M. soybean oil diet.

[2]Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition. Iowa State University Press, Ames, Iowa. p.317.

Table 33

Serum Free Glycerol Concentrations Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[1]

Subjects		Mixed Fat	Soybean Oil	Canbra Oil
		mg/100 ml. free glycerol calculated as triglycerides		
1. H.R.	Re.	3.22	1.47	1.98
	Ex.	2.44	3.19	3.10
	Rec.	3.67	4.47	2.06
2. G.C.	Re.	3.01	3.10	2.06
	Ex.	1.41	3.44	2.07
	Rec.	2.32	3.18	2.33
3. T.T.	Re.	4.73	3.00	1.12
	Ex.	2.58	2.93	2.93
	Rec.	3.18	2.41	3.27
4. S.M.	Re.	2.83	2.24	3.10
	Ex.	3.78	3.27	3.78
	Rec.	3.96	2.84	2.75
Group Mean (N = 4)	Re.	3.45	2.45	2.07
	Ex.	2.55	3.21	2.97
	Rec.	3.28	3.23	2.60
SD ±	Re.	0.87	0.76	0.81
	Ex.	0.97	0.21	0.70
	Rec.	0.75	0.89	0.53

[1]After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

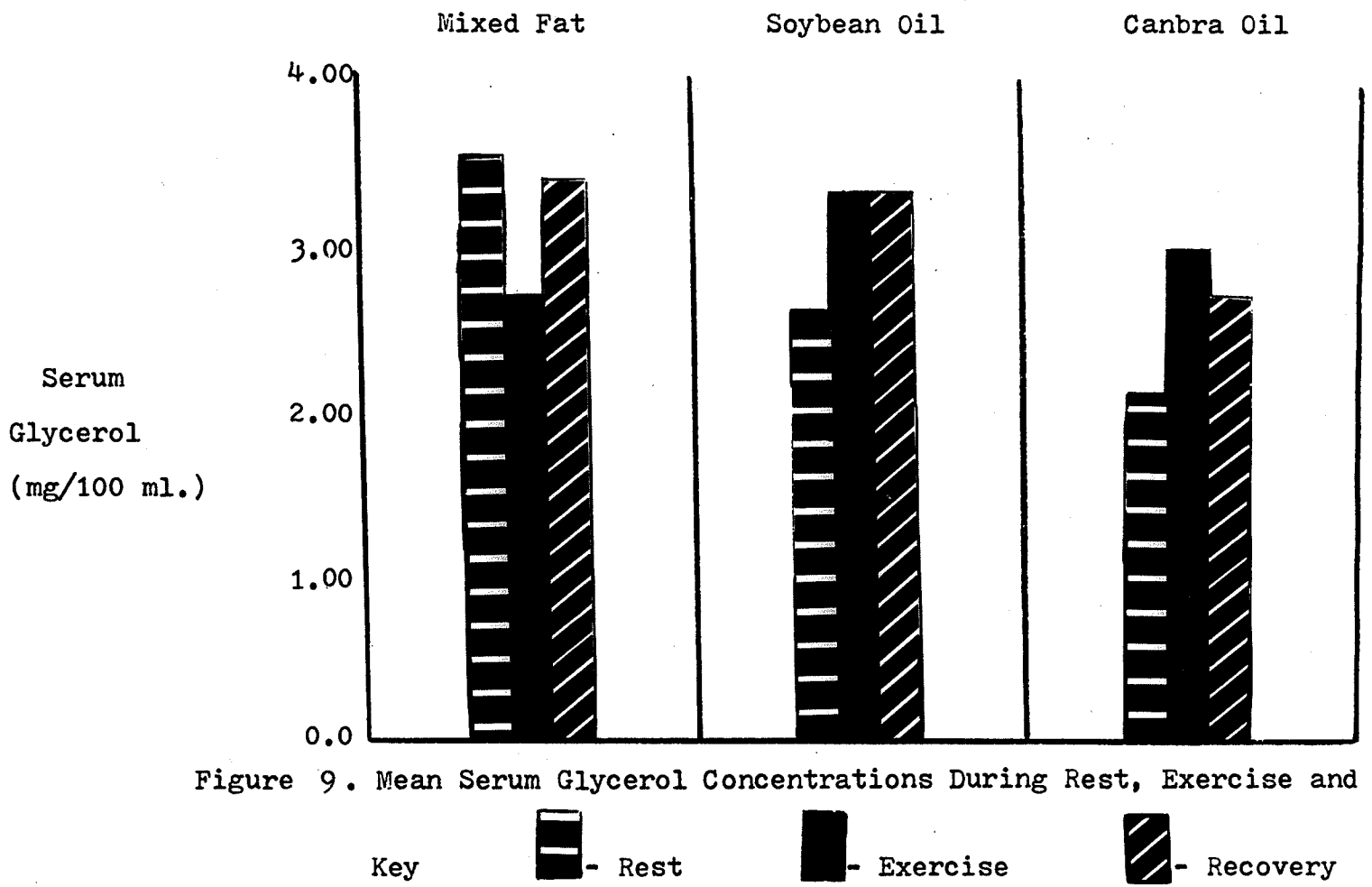

Figure 9. Mean Serum Glycerol Concentrations During Rest, Exercise and Recovery.

The fourth subject (S.M.) exhibited an increase in free glycerol concentration during exercise. Two subjects (H.R. and S.M.) had higher free serum glycerol concentrations during exercise than at rest on both experimental diets, one other subject (G.C.) had a higher free glycerol concentration during exercise only on the soybean oil diet with no change in serum glycerol concentration on the canbra oil diet, while the fourth subject (T.T.) had a higher serum glycerol concentration during exercise only on the canbra oil diet with no change on the soybean oil diet. Similarly there was no consistant change in free serum glycerol concentrations during the recovery period with any of the three fat sources. Thus, there was no significant difference (α=.01) in serum glycerol concentrations between the experimental fat sources (Appendix Table 25).

The slight increase in mean serum free glycerol for the soybean and canbra oil diets (Table 33) during exercise coincided with the decrease in blood glucose (Table 25). Shafrin and Gorin (1963) have reported that changes in glucose in fasting men were followed by reciprocal fluctuations in both free fatty acids and glycerol levels. Although the increase in respiratory quotient during exercise on the soybean and canbra oil diets would indicate an increase in carbohydrate utilization there was also an increase in fat utilization during exercise, as evidenced by the slight increase in free glycerol on these dietary fat sources.

E. Effect of Diet on Certain Lipid Parameters

E.1. Cholesterol

Although serum cholesterol levels can be decreased by long term exercising (conditioning) (Vial et al., 1971) changes in fatty acid composition of the diet bring about a more immediate reduction in serum cholesterol. Keys et al. (1957) have suggested that changes in serum cholesterol levels can be predicted from the changes in fatty acid composition of the diet when these changes are expressed in terms of calories.

Mean serum cholesterol decreased 32 mg/100 ml. of serum (Table 34 and Figure 10) in response to the mixed fat diet. The decrease in serum cholesterol on the mixed fat diet in this study was similar to that observed by Le Blanc (1973), and was greater than that observed by Huisman (1974). The present diet differed from those used by Le Blanc (1973) and Huisman (1974) in the amount of textured soy protein and the composition of the mixed fat used although the saturated to unsaturated fatty acid ratios were similar for the three studies.

It might be recalled that the ratio of saturated: oleic: linolenic fatty acids used in the mixed fat diet in this study was appreciably different from that used by Le Blanc (1973). It was felt that this change would result in a smaller decrease in serum cholesterol than that observed by Le Blanc (1973). However, even with this modification the decrease in serum

Table 34

Serum Cholesterol Levels Observed

During the Experiment

Subjects	Days of Experiment[1]			
	1	9	23	33
	Mg cholesterol/100 ml. serum			
1. H.R.	229	194[2]	182	159
2. G.C.	214	193	185	166
3. T.T.	193	156	138	124
4. S.M.	220	185	158	173
Mean				
(Subjects 1 & 2)	222	194	184	163
(Subjects 3 & 4)	207	171	148	149

[1]Experimental protocol: Day 1 initial observation; Day 9 end of mixed fat diet (all subjects); Day 23 end of soybean oil diet for H.R. and G.C., and end of canbra oil diet for T.T. and S.M.; Day 33 end of canbra oil diet for H.R. and G.C., and end of soybean oil diet for T.T. and S.M.

[2]Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition, Iowa State University Press, Ames, Iowa, p.317.

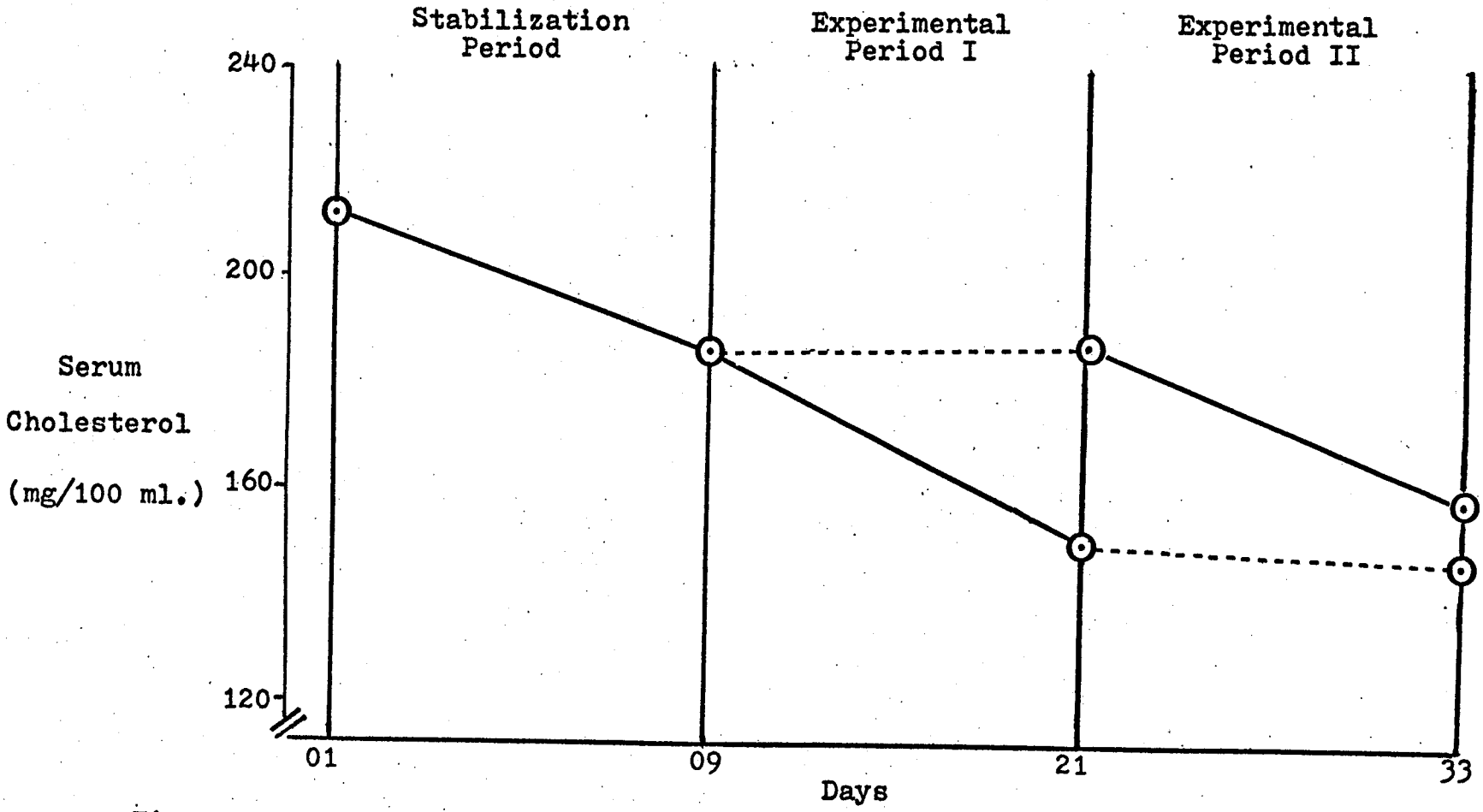

Figure 10. Mean Serum Cholesterol Levels During Experiment.

Key: ----------Soybean Oil Diet; ——————Canbra Oil Diet

cholesterol on the mixed fat diet (32 mg/100 ml.; Table 35) was of the same magnitude as that reported by Le Blanc (1973) (29 mg/100 ml.). Thus it was apparent that changes in serum cholesterol were not due strictly to the fat component of the diet. Carroll and Hamilton (1974) reported that serum cholesterol was considerably lower in rabbits fed plant protein than in rabbits fed animal protein.

For the two subjects T.T. and S.M. placed on the canbra oil diet immediately after the mixed fat diet, the mean decrease in serum cholesterol was 23 mg/100 ml. or 2.1 mg/100 ml./day. No further decrease in mean serum cholesterol occurred when these subjects, T.T. and S.M., were changed to the soybean oil diet(for the final 11 days of the study) because serum cholesterol increased for one subject and decreased for the other. When the other two subjects, H.R. and G.C., were placed on the soybean oil diet immediately after the mixed fat diet, the mean decrease in serum cholesterol was 10 mg/100 ml. or 0.9 mg/100 ml./day. A further decrease in mean serum cholesterol of 21 mg/100 ml., occurred when these two subjects, H.R. and G.C., were changed to the canbra oil diet. However there was no significant difference (α=.01) in serum cholesterol between the soybean oil periods and the canbra oil periods (Appendix Table 26). The absolute decrease in serum cholesterol on the canbra oil diet was of the same magnitude whether the experimental fat was introduced after the mixed fat diet or following the soybean oil diet. However the same situation did not prevail

Table 35

Quantitative Changes Observed in Serum Cholesterol During the Experiment[1]

Subjects	Day 9 vs. 1	Day 21 vs. 9	Day 21 vs. 33
	Mg cholesterol/100 ml. serum		
1. H.R.	-35	-12	-23
2. G.C.	-21	-8	-19
3. T.T.	-37	-18	-14
4. S.M.	-35	-27	+15

[1]Experimental Protocol: Day 1 initial observation; Day 9 end of mixed fat diet (all subjects); Day 23 end of soybean oil diet for H.R. and G.C., and end of canbra oil diet for T.T. and S.M.; Day 33 end of canbra oil diet for H.R. and G.C., and end of soybean oil diet for T.T. and S.M.

with the soybean oil. This apparent discrepancy was due to subject S.M. whose serum cholesterol increased on the soybean oil diet (Table 35).

Le Blanc (1973) observed a decrease of 15 mg in serum cholesterol (2.1 mg/100 ml./day) in subjects after one week of ingesting a canbra oil diet following 10 days on a mixed fat diet. A further decrease in serum cholesterol of 15 mg (1.0 mg/100 ml./day) occurred during the subsequent two weeks of the three week experiment. Other investigators (Keys et al., 1957; Losier, 1972; Huisman, 1974) also found that the major change in serum cholesterol occurred in the first week following dietary manipulation.

The expected decrease in serum cholesterol as a result of substituting the canbra oil diet for the mixed fat diet, according to the Keys equation (Keys et al., 1965) would have been 17 mg/100 ml. whereas the actual decrease observed in the present study was 23 mg/100 ml. (Table 36). The actual decrease in serum cholesterol (10 mg/100 ml.) observed when the soybean oil diet was substituted for the mixed fat diet was substantially smaller than the decrease expected (28 mg/100 ml.) according to the Keys equation (Keys et al., 1965). Changing from the canbra oil diet to the soybean oil diet should have resulted in a very small decrease of 4 mg of cholesterol/100 ml. serum while the opposite change would be expected to result in an increase of 4 mg/100 ml. (Table 37). In the present study there was a decrease of 21 mg cholesterol when the canbra oil diet was

Table 36

Changes in Serum Cholesterol In Response to Mixed Fat, Soybean and Canbra Oil Diets

Diet	% Total Daily Fatty Acids		% of Total Calories from Fat	Change Expressed as % of Total Caloric Fat Intake	
	S^1[1]	P[2]		S^1	P
Mixed Fat	23.2	23.2	37.40		
Soybean Oil	11.3	37.4	37.40	-4.45	5.31
Canbra Oil	6.9	18.8	37.40	-6.10	-1.65

According to Keys et al., 1965: $\Delta C = 1.2\ (2\Delta s^1 - \Delta P)$

Soybean Oil $\Delta C = -27.73$

Canbra Oil $\Delta C = -16.62$

[1] S^1: Total saturated fatty acids minus stearic acid.

[2] P: Total polyunsaturated fatty acids.

ΔC is the change in cholesterol level in mg/100 ml.,

ΔS^1 is the change in the total C12 to C16 saturated fatty acids,

ΔP is the change in the total polyunsaturated fatty acids,

ΔS^1 and ΔP expressed in terms of total calories in the diet.

Table 37

Changes in Serum Cholesterol in Response to Changes in Dietary Fat Source

Diet	% Total Daily Fatty Acids		% of Total Calories From Fat	Change Expressed as % of Total Caloric Fat Intake	
	1 S[1]	2 P		S[1]	P
Soybean	11.3	37.4	37.40		
Canbra	6.9	18.8		-1.65	-6.96
Canbra	6.9	18.8	37.40		
Soybean	11.3	37.4		1.65	6.96

Canbra Oil $\Delta C = 4.39$

Soybean Oil $\Delta C = -4.39$

Legend same as Table 36.

substituted for the soybean oil diet whereas there was no change in serum cholesterol when the soybean oil diet was substituted for the canbra oil diet. Other investigators (Grande et al., 1962; Losier, 1972; Le Blanc, 1973; Huisman, 1974) have observed discrepancies in expected and observed changes in serum cholesterol in response to specific dietary fats. Although Le Blanc (1973) observed a greater discrepancy in predicted and observed changes in serum cholesterol than was observed in the present study, the rates of decrease in serum cholesterol were identical on the two canbra oil studies.

E.2. Triglycerides

Changes in serum triglyceride levels are more responsive to changes in dietary fatty acid composition than to increased physical activity. Saturated fatty acids with fewer than 12 carbon atoms and stearic acid are known to produce elevated serum triglyceride levels (Grande et al., 1972). Like cholesterol and lipid phosphrus, little or no change is observed in triglyceride levels during occasional mild exercise.

Mean serum triglyceride levels decreased 43 mg/100 ml. on the mixed fat diet (Tables 38, 39, and Figure 11). This large decrease was due mainly to two subjects, T.T. and S.M., whose serum triglyceride levels, which were high at the beginning of the experiment, decreased substantially during the stabilization period. The variation among subjects was greater on the mixed fat diet than on either the

Table 38

Serum Triglyceride Levels Observed During the Experiment

Subjects	Days of Experiment[1]			
	1	9	23	33
	Mg triglyceride/100 ml. serum			
1. H.R.	101	80[2]	88	89
2. G.C.	94	74	78	65
3. T.T.	182	103	93	89
4. S.M.	154	94	92	84
Mean				
(Subjects 1 & 2)	98	77	83	77
(Subjects 3 & 4)	168	97	93	87

[1]Experimental protocol: Day 1 initial observation; Day 9 end of mixed fat diet (all subjects); Day 23 end of soybean oil diet for H.R. and G.C., and end of canbra oil diet for T.T. and S.M.,; Day 33 end of canbra oil diet for H.R. and G.C., and end of soybean oil diet for T.T. and S.M.

[2]Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition, Iowa State University Press, Ames, Iowa, p.317.

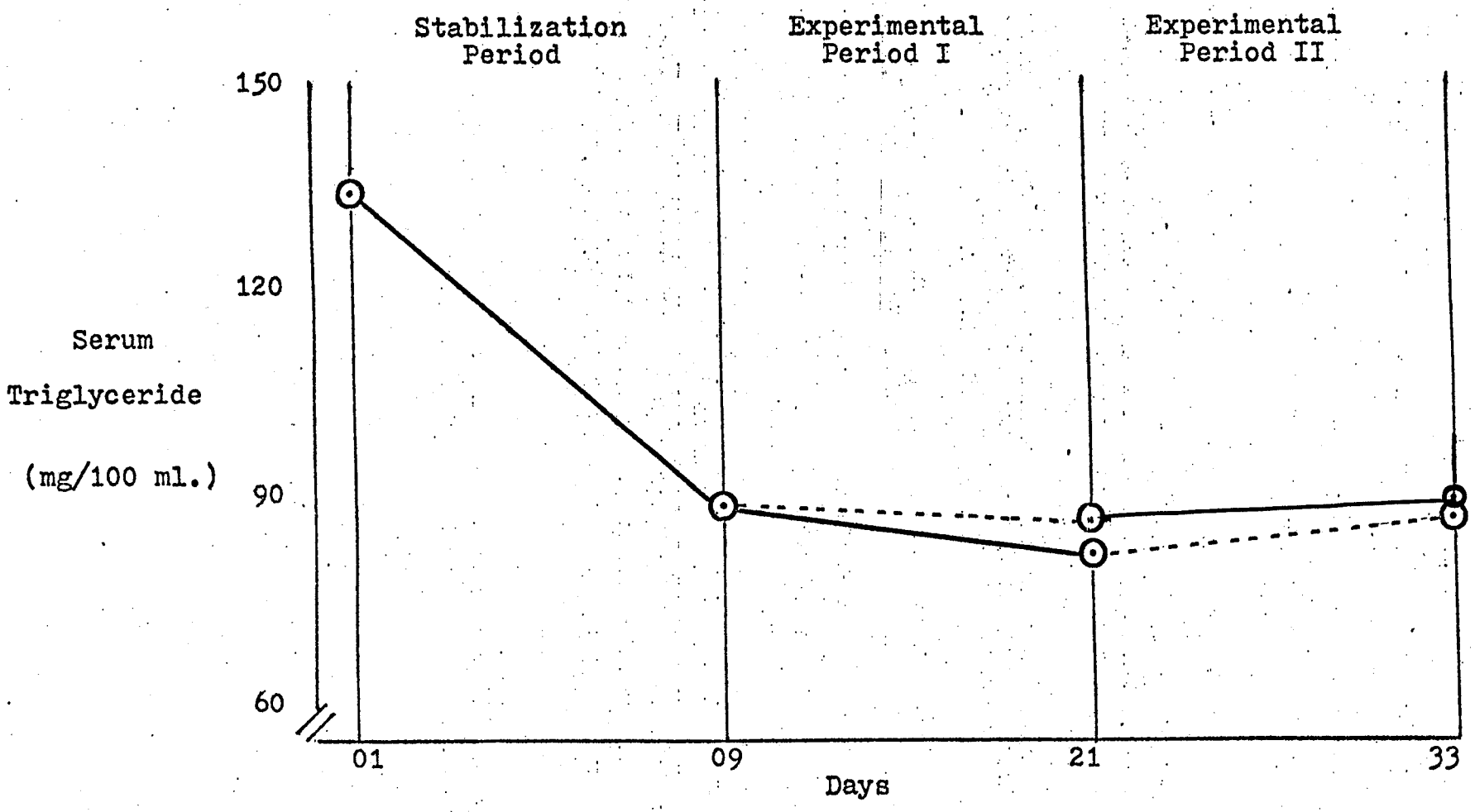

Figure 11. Mean Serum Triglyceride Levels During Experiment.

Key: ----------Soybean Oil Diet; ——————Canbra Oil Diet

Table 39

Quantitative Changes Observed in Serum Triglycerides During the Experiment[1]

Subjects	Day 9 vs. 1	Day 21 vs. 9	Day 21 vs. 33
	Mg Triglyceride/100 ml. serum		
1. H.R.	-21	+8	+1
2. G.C.	-20	+4	-13
3. T.T.	-79	-10	-4
4. S.M.	-60	-2	-8

[1]Experimental Protocol: Day 1 initial observation; Day 9 end of mixed fat diet (all subjects); Day 23 end of soybean oil diet for H.R. and G.C., and end of canbra oil diet for T.T. and S.M.; Day 33 end of canbra oil diet for H.R. and G.C., and end of soybean oil diet for T.T. and S.M.

soybean or canbra oil diets. The mean serum triglyceride level increased only slightly (6 mg/100 ml.) for the two subjects, H.R. and G.C., placed on the soybean oil diet immediately following the mixed fat diet (Table 38). This increase on the soybean oil diet was followed by a reciprocal decrease when the soybean oil diet was replaced by the canbra oil diet. The mean serum triglyceride level decreased 4 mg/100 ml. when subjects T.T. and S.M. were placed on the canbra oil diet immediately following the mixed fat diet. This small decrease on the canbra oil diet was followed by a further decrease (6 mg/100 ml.) when the soybean oil diet was substituted for the canbra oil diet. Therefore no significant difference (α =.01) was observed in serum triglyceride levels between the experimental diets (Appendix Table 28). The fact that the mean serum triglyceride levels were identical on the soybean and canbra oil diets was apparently due to the similar stearic acid content of the two diets (Table 14).

In the present study the mean decrease in serum triglycerides (6 mg/100 ml.) for the canbra oil diet was identical to that observed by Le Blanc (1973) at the end of three weeks on a canbra oil diet. However, it might have been interesting to continue the present study for a longer time since Le Blanc (1973) reported that the major change in serum triglycerides in response to dietary fat source occurred during the third week on the canbra oil diet. The observation of Le Blanc (1973) was in contrast to that of Huisman (1974) who reported a significant (P=.005) decrease

in serum triglycerides during the first week on a high erucic acid rapeseed oil diet.

E.3. Lipid Phosphorus

No specific dietary fatty acids or class of fatty acids have been found to affect serum lipid phosphorus. Several investigators (McGandy et al., 1970; Losier, 1972; Le Blanc, 1973; Huisman, 1974) have reported that the pattern of change in serum lipid phosphorus in response to a change in diet follows the same pattern as serum cholesterol, although the change in lipid phosphorus tends to lag behind cholesterol.

A slight decrease was observed in mean serum lipid phosphorus levels for all three diets fed in the present study (Tables 40 and Figure 12). The trend was consistent for all subjects throughout the experiment. The decreases in lipid phosphorus on the soybean and canbra oil diets were 0.13 mg/100 ml./day and 0.10 mg/100 ml./day, respectively. However there were no significant difference (α=.01) between the soybean and canbra oil diets for lipid phosphorus (Appendix Table 29). The observed decrease on the canbra oil diet (Table 41) was slightly less than that reported by Le Blanc (1973) (0.15mg/100 ml./day) but slightly greater than that reported by Huisman (1974) (0.05 mg/100 ml./day) after eight days of ingesting canbra oil or high erucic acid rapeseed oil, respectively. Mean serum lipid phosphorus levels were in general, higher in the Le Blanc (1973) and

Table 40

Serum Lipid Phosphorus Levels Observed During the Experiment

Subjects	Days of Experiment[1]			
	1	9	23	33
	Mg lipid phosphorus/100 ml. serum			
1. H.R.	6.3	5.9[2]	5.3	4.7
2. G.C.	7.2	6.3	5.3	5.6
3. T.T.	6.9	5.9	5.3	4.4
4. S.M.	7.5	6.6	5.3	5.0
Mean				
(Subjects 1 & 2)	6.8	6.1	5.3	5.2
(Subjects 3 & 4)	7.2	6.3	5.3	4.7

[1]Experimental protocol: Day 1 initial observation; Day 9 end of mixed fat diet (all subjects); Day 23 end of soybean oil diet for H.R. and G.C., and end of canbra oil diet for T.T. and S.M.; Day 33 end of canbra oil diet for H.R. and G.C., and end of soybean oil diet for T.T. and S.M.

[2]Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6thEdition, Iowa State University Press, Ames, Iowa, p.317.

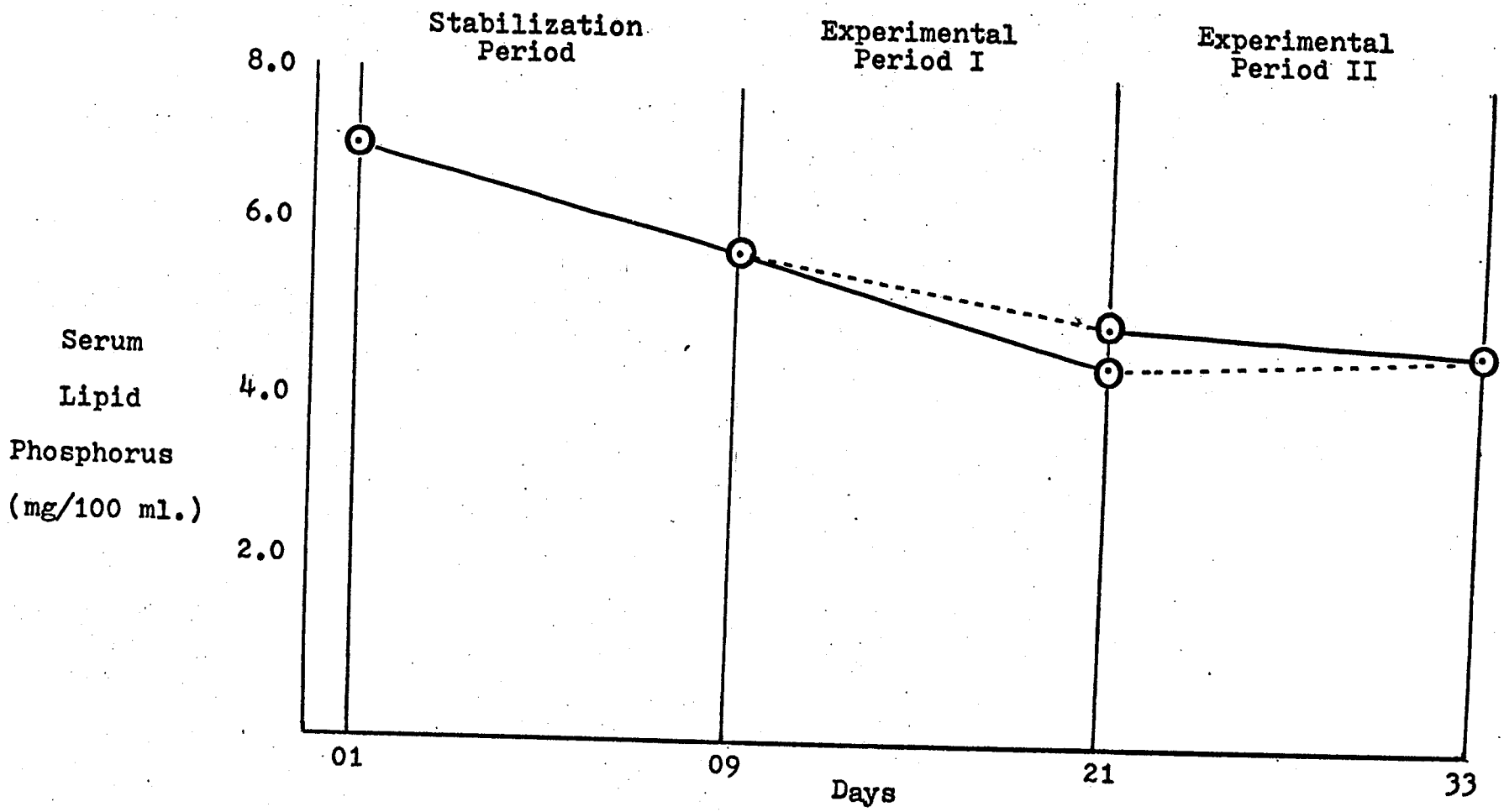

Figure 12. Mean Serum Lipid Phosphorus Levels During Experiment.

Key: ----------Soybean Oil Diet; ——————Canbra Oil Diet

Table 41

Quantitative Changes Observed in Serum Lipid Phosphorus During the Experiment[1]

Subjects	Day 9 vs. 1	Day 21 vs. 9	Day 21 vs. 33
	Mg lipid phosphorus/100 ml. serum		
1. H.R.	-0.4	-0.6	-0.6
2. G.C.	-0.9	-1.0	+0.3
3. T.T.	-1.0	-0.6	-0.9
4. S.M.	-0.9	-1.3	-0.3

[1]Experimental Protocol: Day 1 initial observation; Day 9 end of mixed fat diet (all subjects); Day 23 end of soybean oil diet for H.R. and G.C., and end of Canbra Oil diet for T.T. and S.M.; Day 33 end of canbra oil diet for H.R. and G.C., and end of soybean oil diet for T.T. and S.M.

Huisman (1974) studies than in the present study.

F. Whole Blood Hematology

Reports of adverse effects of rapeseed oil on the metabolism of experimental animals date back to 1947. However only a few studies have reported on hematological parameters (Abdellatif et al, 1972; Vles and Abdellatif, 1970a,b,). Decreased hemoglobin, increased reticulocytes and increased red cell fragility were observed in guinea pigs (Vles and Abdellatif, 1970a). Decreased hemoglobin and increased hematocrit have been reported in ducklings fed a mixture of rapeseed oil and hardened palm oil (Abdellatif et al., 1972). Hematological findings in human subjects fed either canbra oil or rapeseed oil also are few. Le Blanc (1973) found no consistent effect of canbra oil on blood hematology. Huisman (1974) in a similar study using high erucic acid rapeseed oil observed significant decreases in leukocyte and platelet counts. Although Le Blanc (1973) did not report on platelet count, Huisman (1974) reviewed her data and found there were no significant changes in platelet count on the canbra oil diet.

Hematological measurements during the present study are presented in Tables 42 to 47. The values for all hematological parameters measured for all subjects were within normal ranges throughout the study. Furthermore no significant differences (α=.01) were observed between the soybean and canbra oil diets (Appendix Tables 30-34)

for any of the hematological parameters measured.

The mean observations for total red blood cell count, hematocrit and haemoglobin on the experimental diets were similar to the mean values found on the mixed fat diet (Tables 42, 43 and 44). However the mean reticulocyte count on the canbra oil diet was slightly higher than on the mixed fat diet (Table 45). In spite of the differences the means were within the range of values considered normal for adults (0.2-2.0% total red cell count) (Dacie and Lewis, 1963). Le Blanc (1973) also reported a significantly higher reticulocyte count when canbra oil was fed. However, as in the present study, all observed values were within the normal range. Reticulocyte counts also were normal in subjects fed high erucic acid rapeseed oil (Huisman, 1974).

In the present study the ingestion of either soybean oil or canbra oil for 10 days resulted in an appreciable decrease in leukocyte counts (Table 46). In spite of these decreases mean leukocyte counts on both experimental diets were within the normal range and there was no significant difference (α=.01) between the experimental fats for leukocyte counts (Appendix Table 34). In contrast to the present finding, Huisman (1974) observed no change in leukocyte counts during the first 8 days on a high erucic acid rapeseed oil diet. However during the second and third weeks of the Huisman study, mean leukocyte counts decreased below normal.

Platelet counts for all subjects remained normal

Table 42

Total Red Cell Count[1] Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[2]

Subjects	Initial	Mixed Fat	Soybean Oil	Canbra Oil
		Millions/cu. mm. of blood		
1. H.R.	5.1	-	5.0	5.1
2. G.C.	5.0	4.9	5.1	5.0
3. T.T.	5.6	3.4	5.5	5.5
4. S.M.	5.2	5.3	5.2	5.2
Group Mean (N = 4)	5.2	4.5	5.2	5.2
SD ±	0.3	1.00	0.2	0.2

Normal Range: 4.5 - 6.5 million /cu. mm. (Dacie and Lewis 1963

[1]As determined by Hematological Laboratories, Winnipeg General Hospital.

[2]After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

Table 43

Hematocrit Values[1] Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[2]

Subjects	Initial	Mixed Fat	Soybean Oil	Canbra Oil
	Percentage of blood that is cells			
1. H.R.	42.0	41.3[3]	41.0	41.5
2. G.C.	45.5	44.5	46.0	45.5
3. T.T.	48.0	45.5	46.5	46.0
4. S.M.	46.5	48.0	46.5	45.5
Group Mean (N = 4)	45.5	44.8	45.0	44.6
SD ±	2.5	2.8	2.7	2.2

Normal Range: 40-56 per cent (Dacie and Lewis, 1963).

[1]As determined by Hematological Laboratories, Winnipeg General Hospital.

[2]After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

[3]Calculated value according to Snedecor, G. W. and Cochran, W. G. 1967. Statistical Methods, 6th Edition. Iowa State University Press, Ames, Iowa. p. 317.

Table 44

Haemoglobin Values[1] Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[2]

Subjects	Initial	Mixed Fat	Soybean Oil	Canbra Oil
		Grams/100 ml. blood		
1. H.R.	14.6	14.4[3]	14.1	14.1
2. G.C.	16.2	15.7	16.4	15.4
3. T.T.	17.0	16.3	15.8	16.2
4. S.M.	16.0	16.8	16.1	15.9
Group Mean (N = 4)	16.0	15.8	15.6	15.4
SD ±	1.0	1.0	1.0	0.9

Normal Range: 13.5 - 18.0 grams/100 ml. blood (Dacie and Lewis, 1963)

[1]As determined by Hematological Laboratories, Winnipeg General Hospital.

[2]After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

[3]Calculated value according to Snedecor, G. W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition. Iowa State University Press, Ames, Iowa. p. 317.

Table 45

Reticulocyte Count[1] Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[2]

Subjects	Initial	Mixed Fat	Soybean Oil	Canbra Oil
	thousands/cu. mm. of blood			
1. H.R.	15.3	43.3[3]	35.0	55.0
2. G.C.	20.0	58.8	35.7	50.0
3. T.T.	39.2	21.6	38.5	44.2
4. S.M.	20.8	53.0	41.5	36.2
Group Mean (n=4)	23.8	44.2	37.9	46.4
% Total Red Blood Cells	0.5	1.0	0.7	0.9
SD±	10.5	16.4	3.0	8.1
Normal Range (Adults)	0.2 - 2.0 per cent total red blood cells (Dacie and Lewis, 1963).			

[1]As determined by Hematological Laboratories, Winnipeg General Hospital.

[2]After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

[3]Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition, Iowa State University Press, Ames, Iowa, p.317.

Table 46

Leukocyte Count[1] Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[2]

Subjects	Initial	Mixed Fat	Soybean Oil	Canbra Oil
		Thousands/cu. mm. of blood		
1. H.R.	5.5	7.5[3]	4.9	5.0
2. G.C.	8.1	5.8	6.5	4.8
3. T.T.	11.0	10.6	7.5	6.1
4. S.M.	8.0	11.3	5.3	4.6
Group Mean (N = 4)	8.2	8.8	6.1	5.1
SD ±	2.2	2.6	1.2	0.7

Normal Range: 4-10 Thousand/cc. mm. (Dacie and Lewis, 1963).

[1] As determined by Hematological Laboratories, Winnipeg General Hospital.

[2] After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

[3] Calculated value according to Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods, 6th Edition. Iowa State University Press, Ames, Iowa. p. 317.

for the duration of the study (Table 47). This observation was in agreement with work previously done in our laboratory demonstrating that canbra oil had no deleterious effect on platelet counts in young men. By contrast, the ingestion of high erucic acid rapeseed oil decreases platelet counts in young male subjects (Huisman, 1974). Very little has been reported on the effect of specific fatty acids or fats on platelet count. However some investigators (Hoak et al., 1967; Silver et al., 1974) have cited certain fatty acids as having a thrombogenic effect, namely platelet aggregation.

G. Comparison of Observations After A Single Meal and After A Similar Meal Following the Ingesting Of The Experimental Fats for Ten Days

During experimental Periods I and II both respiratory exchange and the concentration of blood metabolites were monitored after a single meal containing 68 grams of either soybean oil or canbra oil and again after a similar meal following the ingestion of the experimental fats for 10 days. In addition resting respiratory exchange measurements were monitored after an overnight fast on the morning of the last day of each experimental period. The results of the resting respiratory exchange were reported only for RQ (Table 22).

Respiratory parameters (respirators quotient and oxygen consumption) and the concentration of blood metabolites (glucose, glycerol, lactate and pyruvate) were similar after a single meal and after a similar meal following 10 days

Table 47

Platelet Count[1] Grouped According to Dietary Treatment for Subjects Fed the Diet for 8 or 10 Days[2]

Subjects	Initial	Mixed Fat	Soybean Oil	Canbra Oil
1. H.R.	N	-	N	N
2. G.C.	N	N	N	N
3. T.T.	N	-	-	N
4. S.M.	N	N	N	N
Group Mean	4/4N	2/2N	3/3N	4/4N

Symbol: N = Normal range ($\geq$ 150 thousand/cu. mm) (Guyton, 1971).

\- indicate no sample or no result reported.

[1]As determined by Hematological Laboratories, Winnipeg General Hospital.

[2]After 8 days on the mixed fat diet and 10 days on the soybean and canbra oil diets.

of ingesting either the soybean oil or canbra oil diets. Since fasting and resting respiratory parameters after 10 days of ingesting the experimental fats were similar to resting respiratory parameters after a single meal of these oils and after 8 days on the mixed fat diet it was concluded that respiratory exchange was not affected by a single meal or prolonged feeding of either soybean oil or canbra oil. Even with the stress of exercise there was no indication that respiratory exchange was affected by these fat sources. Likewise, since the concentration of blood metabolites at rest after 10 days of ingesting either soybean oil or canbra oil did not differ from the concentrations observed after a single meal of these oils, or from the concentrations observed after 8 days on the mixed fat diet, it was concluded that these blood metabolites were not affected by dietary fat source. As with respiratory exchange, blood metabolites were not affected by dietary fat source even during exercise. Thus energy metabolism was not affected by dietary fat source after a single meal or after prolonged feeding.

The work of Trémolières et al. (1971) and Tremolieres and Carrè (1972) indicated that energy metabolism measured at 2.5 or 3.0 hours after the ingestion of high erucic acid was altered. In the Trémolières et al. (1971) and Trémolières and Carrè (1972) studies respiratory quotients measured at 2.5 and 3.0 hours after the ingestion of high erucic acid rapeseed oil were considerably lower

than RQ measurements after the ingestion of peanut oil. By contrast, in the present study neither soybean oil nor canbra oil caused any decrease in RQ when compared to the mixed fat diet. The differences in erucic acid content of the oils (43% vs. 0.4%) and the means of administering the oils (single dose of oil on an empty stomach vs. oil incorporated into a mixed diet) may have been responsible for the differences observed in RQs in the present study and the Trémolières et al. (1971) and Trémolières and Carrè (1972) studies.

H. General Discussion

The investigation of energy metabolism in young men ingesting canbra oil or soybean oil revealed that energy metabolism was not affected by dietary fat source. Changes observed for the soybean oil diet and the canbra oil diet were similar. Subjecting the subjects to the stress of exercise resulted in a several fold increase in respiratory exchange measurements and in blood metabolites such as lactate, pyruvate and glycerol. These changes were accompanied by a decrease in serum glucose. The increase in energy expenditure and the concomitant decrease in serum glucose coincided with an increase in respiratory quotients. Although the changes in serum glucose and respiratory quotients during exercise indicated that the primary change was an increased utilization of carbohydrate by the working muscle, there was also a small increase in free glycerol

suggesting that there was a concomitant increase in fat utilization to meet the marked increase in energy expenditure accompanying work. The similarity of the respiratory quotients during exercise for all three diets (mixed fat 0.91; soybean 0.94; canbra 0.92) indicated no difference in substrate being matabolized during exercise when either of the experimental diets were substituted for the mixed fat diet. Furthermore, there was no indication on the basis of RQ, of preferential oxidation of the fatty acids on either of the experimental diets during exercise or during rest. By contrast Trémolières et al. (1971) and Trémolières and Carre (1972) reported preferential oxidation of the fatty acids during rest following the ingestion of high erucic acid rapeseed oil. Trémolières et al. (1971) and Trémolières and Carre (1972) based their conclusion on the fact that they found a substantial decrease in RQ at rest 2.5 or 3.0 hours after the ingestion of high erucic acid rapeseed oil. Houtsmuller et al. (1970) found that high erucic acid rapeseed oil inhibited the mitochondrial oxidation of various substrates (glutamate, oxoglutarate, succinate, malate) while Christophersen and Bremer (1972) reported that a mitochondrial metabolite of erucic acid inhibited the mitochondrial oxidation of other fatty acids. Preferential oxidation of palmitate or oleate in the presence of erucate has been reported (Swarttouw, 1974). However impaired oxidation of erucate did not fully explain the preferential oxidation of palmitate or oleate and Swarttouw (1974) did

not rule out the possibility that differences in transport of fatty acids to the site of oxidation might account for the preferential oxidation of palmitate or oleate in the presence of erucate.

It is difficult to compare changes in blood metabolites in the present study with those of Trémolières et al. (1971) since the observations were not made at comparable times. In the present study in contrast to the Trémolières study (1971), respiratory exchange measurements and blood metabolite concentrations were investigated at similar times. In the Trémolières study no observation was made of changes in the concentration of blood metabolites immediately after exercise. However the observations made by Trémolières et al. (1971) 2.5 hours after the ingestion of the test fat (rapeseed or peanut oils) have been considered comparable to the rest period in the present study and their observation one hour later to the recovery period in the present study.

The increased metabolic stress as a result of exercise resulted in an increase in the concentrations of lactate and pyruvate and in oxygen consumption to meet the increased energy demand of the body. Neither the soybean oil nor the canbra oil diets when compared to the mixed fat diet, had any curbing effect on oxygen consumption during exercise. This was in contrast to the observation of Trémolières et al. (1971) who found that the ingestion of

a single dose of rapeseed oil depressed oxygen consumption during exercise.

Oxygen uptake in the liver and heart mitochondria of rats fed high erucic acid rapeseed oil has been shown to be depressed when erucylcarnitine served as substrate (Christophersen and Bremer, 1972). Similarly other investigators (Houtsmuller et al., 1970; Kramer et al., 1973) have reported impaired respiratory activity with a number of substrates in the heart mitochondria of rats fed high erucic acid rapeseed oil. However there is a discrepancy between the Houtsmuller and Kramer studies as to the degree of impairment. Kramer et al. (1973) suggested that the marked impairment in respiratory activity observed by Houtsmuller et al. (1970) was the result of improper mitochondrial isolation. Although Trémolierès et al. (1971) reported decrease oxygen consumption during exercise and depressed respiratory quotients during rest, the fact that the muscle mitochondrial function was not impaired, as reflected by the lactate/pyruvate ratios, indicated that the mitochondria were capable of coping with the substrate being utilized. There was no evidence in the present study that the function of muscle mitochondria was impaired by either of the experimental fats. It is noteworthy that indirect evaluation of the function of intact muscle mitochondria in man revealed no detrimental effect after the ingestion of a single dose of rapeseed oil (Trémolierès et al., 1971), a single meal of canbra oil, or even after

prolonged feeding of high levels of canbra oil.

The effects of dietary fat on serum lipids have been extensively studied. Fatty acids are known to have differing effects depending on the serum lipid parameter measured. Changes in serum cholesterol have been shown to be primarily associated with polyunsaturated fatty acids and saturated fatty acids containing 12 to 16 carbon atoms, while the monosaturated fatty acids have little or no effect (Keys et al., 1957; 1958; Hegsted et al., 1965). Grande et al. (1972) have suggested that saturated fatty acids with fewer than 12 carbon atoms and more than 16 carbon atoms (viz. stearic acid) produce an elevation in serum triglycerides, but have little effect on serum cholesterol. No specific dietary fatty acids or class of fatty acids have been found to alter serum lipid phosphorus. However several investigators have reported changes in serum lipid phosphorus patterns similar to changes in serum cholesterol patterns (McGandy et al., 1970; Losier, 1972; Le Blanc 1973; Huisman, 1974).

In the present study the main difference between the stabilization diet and the experimental diets was the degree of saturation; the mixed fat diet was appreciably higher in saturated fatty acids. On the basis of Keys equation (Keys et al. 1965) the expected decrease in serum cholesterol as a result of substituting the canbra oil diet for the mixed fat diet would be 17 mg/100 ml. of serum. However the observed decrease was 23 mg/100 ml. serum.

For the soybean oil diet the reverse situation prevailed; the observed decrease (10 mg/100 ml.) was considerably less than predicted (28 mg/100 ml.). Although discrepancies in observed and predicted changes in serum cholesterol have been observed by other workers (Ravensdale, 1972; Le Blanc, 1973; Huisman, 1974) the reason has not been fully elucidated.

Mean serum triglyceride levels on the soybean and canbra oil diets were similar. This close similarity in mean serum triglyceride levels on the experimental diets was apparently due to their similarity in stearic acid content.

Lipid phosphorus decreased 0.13 mg/100 ml./day on the soybean oil diet and 0.11 mg/100 ml./day on the canbra oil diet. The decrease on the canbra oil diet was comparable to that reported by Le Blanc (1973) in a similar study. Other experimenters (Ravensdale, 1972; Huisman, 1974) have found that the change in serum lipid phosphorus, although similar to cholesterol, lags behind cholesterol.

The hematological parameters selected for measurement were considered to adequately reflect the oxygen carrying capacity of the blood and the functioning of the hematopoietic system. Although most of the hematological parameters decreased during the stabilization period, and then fluctuated during the experimental periods, all mean observations were within normal ranges. With the exception of platelet count in the Huisman (1974) study hematological changes in the present study, the Le Blanc (1973) study and

the Huisman (1974) study were similar. The most notable difference between the canbra oil studies (present study and Le Blanc, 1973) and the rapeseed oil study (Huisman, 1974) was the progressive decrease in platelet counts on the high erucic acid rapeseed oil diet. When the mixed fat diet (stabilization diet) was reintroduced for the last seven days of the Huisman study, platelet counts returned to normal in five of seven subjects. Since platelet counts progressively decreased on the high erucic acid rapeseed oil diet and then returned to normal with the reintroduction of the mixed fat diet it was concluded that dietary fat source was responsible for the changes observed in platelet counts (Huisman, 1974). By contrast, there was no evidence in the present study or that of Le Blanc (1973) that canbra oil had any deleterious effect on platelet count.

No differences were found when fasting and resting respiratory parameters after 10 days of ingesting either soybean oil or canbra oil were compared to resting respiratory parameters after a single meal of these oils. Similarly the levels of blood metabolites (glucose, glycerol, lactate, pyruvate) at rest after 10 days on canbra oil and soybean oil diets did not differ from the levels observed at rest after a single meal of these diets. Thus energy metabolism after a single meal of soybean oil or canbra oil did not differ from that after prolonged feeding of these oils.

There was no evidence in the present study that

canbra oil had any deleterious effect on serum lipid patterns, whole blood hematology or energy metabolism at rest or under physical work.

SUMMARY AND CONCLUSIONS

The comparative effect of canbra oil and soybean oil on energy metabolism at rest and under physical work was investigated in four young healthy male college students. The 32-day metabolic study consisted of three experimental periods: a 10-day stabilization period, during which the four subjects received a diet containing a mixed fat; an 11-day experimental period (Period I) during which two subjects received the soybean oil diet and two subjects received the canbra oil diet; and an 11-day experimental period (Period II) during which the diets were switched such that the two subjects receiving the soybean oil diet received the canbra oil diet, and the two subjects receiving the canbra oil diet received the soybean oil diet. Fat provided approximately 38 per cent of the calories in both the stabilization and experimental diets. However the fatty acid composition of the diets differed appreciably. The saturated to unsaturated fatty acid ratios of the diets were 1.0:1.8, 1.0:4.6, 1.0:6.8 for the mixed fat, soybean and canbra oil diets, respectively.

Each subject was exercised for ten minutes at 950 kpm on a bicycle ergometer 2.5 hours after a test meal containing 68 grams of the test fat. Each exercise period was preceded by a twenty minute rest period and followed by a twenty minute recovery period. Respiratory exchange

measurements and blood samples were taken during the rest, exercise and recovery periods on Day 8, 10, 20, 22 and 32. Thus the measurements were made after 8 days on the mixed fat diet and on the first and tenth day of each experimental period. In addition resting respiratory gas exchange following an overnight fast was monitored for twenty minutes on the mornings of Day 22 and 32. Blood samples were analysed for glucose, glycerol, lactate and pyruvate. In addition fasting blood samples were taken on Day 1, 9, 21, and 33, that is, on the morning of the first day of the experiment and on the morning following the last meal of each experimental dietary regimen, for the determination of whole blood hematology and serum lipid patterns.

The four male subjects remained in good health. Body weights remained constant throughout the study and no dietary upsets were encountered.

Mean ventilation rate during exercise for the canbra oil diet was very similar to that on the mixed fat diet, whereas mean ventilation rate on the soybean oil diet tended to be lower than on the mixed fat diet. However the ventilation rate during exercise did not differ significantly ($\alpha = .01$) between the soybean and canbra oil diets. Since changes in ventilation rates were similar on all three diets it was concluded that the changes were due only to exercise and not to dietary fat source.

There was no significant difference ($\alpha=.01$) in energy expenditures (oxygen consumption) for the soybean

oil diet and the canbra oil diet. The experimental diets caused no effect on oxygen consumption during physical work of the intensity used in this study. This observation is in contrast to that of Tremolieres et al. (1971) who found that high erucic acid surpresses oxygen consumption.

Respiratory quotients during rest on the mixed fat, soybean oil and canbra oil diets were 0.78, 0.80 and 0.79, respectively. These values were similar to resting RQ measurements recorded after an overnight fast. Fasting RQ's following ten days on the soybean and canbra oil diets were 0.80 and 0.81, respectively. The similarity of the exercise RQ's on all three diets indicated that there was no difference in substrate being metabolized during exercise when either the soybean oil or canbra oil diets were substituted for the mixed fat diet. Furthermore, on the basis of RQ's there was no indication of preferential oxidation of the fatty acids on either the soybean oil or the canbra oil during rest or exercise.

In general no marked changes in respiratory parameters were observed when either the soybean oil diet or the canbra oil diet was substituted for the mixed fat diet. Similarly respiratory parameters on both the soybean oil diet and the canbra oil diets were similar whether the measurements were made after a single meal or after prolonged feeding of these fats. Thus there was no indication that respiratory parameters were affected by dietary fat

source. On the other hand, the effect of exercise on RQ, ventilation rate and oxygen consumption was clearly demonstrated by increases in these parameters during the exercise period. The decreases in these parameters during recovery signified the return to near resting rates.

The effect of exercise on specific blood parameters was similar for the soybean and canbra oil diets. Mean serum glucose decreased 15 mg/100 ml. during exercise on both the soybean and canbra oil diets. Only on the canbra oil diets was there an increase in serum glucose during the recovery period. However there was no significant difference ($\alpha = .01$) between the soybean and canbra oil diets for serum glucose. Mean serum glucose during the recovery period was lower on the experimental diets than on the mixed fat diet, although the differences were not significant. The greater decrease (33 vs. 15 mg/100 ml.) in serum glucose concentration during exercise on the mixed fat diet than on the experimental diets was unexplainable.

Although both lactate and pyruvate concentrations increased during exercise on the stabilization and experimental diets, the magnitude of increase in lactate (295-374 μmoles/100 ml.) was greater than that of pyruvate (9-15 μmoles/100 ml.). Nevertheless the resulting lactate/pyruvate ratios were similar on the soybean (27) and canbra oil (25) diets. Assuming that the lactate/pyruvate ratio is proportional to the ratio of the concentrations of the reduced to the oxidized form of diphosphopyridine nucleotide ([DPNH][H+]/[DPN]), and thus reflects the oxidation-reduction potential

of the tissue, it was concluded that the oxidation-reduction potential of the tissues was not altered during exercise when the soybean or canbra oil diets were substituted for the mixed fat diet.

Mean serum free glycerol concentrations increased slightly during the exercise period on both the soybean and canbra oil diets. This increase coincided with a decrease in serum glucose levels. This observation suggests there was an increased utilization of fatty acids during exercise, in spite of the marked increase in RQ. However, it is possible that the increase in serum glycerol concentration was in fact due to a decreased removal of glycerol by the liver as a result of decreased hepatic blood flow during exercise rather than to an increased production of glycerol per se. There was no significant difference (α = .01) between the experimental fat sources for serum glycerol.

Like the respiratory parameters, observations for serum glucose, glycerol, lactate, pyruvate and the lactate/pyruvate ratio after a single meal of either soybean oil or canbra oil were not markedly different from observations after a similar meal following ten days of ingesting these oils. Thus it was concluded that energy metabolism, as reflected by respiratory exchange and the concentration of specific blood metabolites, was not affected by dietary fat source.

Mean serum cholesterol decreased significantly (α = .01) on the mixed fat diet (Appendix Table 27). Small decreases in mean serum cholesterol also were observed on

both experimental diets and there was no significant difference (α = .01) in serum cholesterol between the experimental fats. On the canbra oil diet, the predicted decrease in serum cholesterol (17 mg/100 ml.) on the basis of the Keys equation (Keys et al., 1957) was slightly less than the observed (23 mg/100 ml.) decrease. The reverse situation prevailed for the soybean oil diet; the observed decrease (10 mg/100 ml.) was considerably less than predicted (28 mg/100 ml.). The rate of decrease of serum cholesterol on the canbra oil diet was identical to that reported by LeBlanc (1973), and in both studies there were discrepancies between the observed and the predicted change in serum cholesterol according to the Keys formular (Keys et al. 1957).

Mean serum triglyceride levels decreased 43 mg/100 ml. on the mixed fat diet. Substitution of the soybean oil or canbra oil diets for the mixed fat diet resulted in no further marked decrease. This observation may be due to the fact that the soybean and canbra oil diets contained similar levels of stearic acid.

No marked change in serum lipid phosphorus was observed during the study. The mean decreases in serum lipid phosphorus on the soybean and canbra oil diets were 0.13 mg/100 ml./day and 0.10 mg/100 ml./day, respectively. The importance of changes in serum lipid phosphorus levels has not been ascertained. However the changes observed in serum cholesterol and triglyceride levels on the canbra oil diets

were considered desirable, in light of the present knowledge on the relationship between serum lipid patterns and atherosclerosis.

The values for all hematogolical parameters measured were within normal ranges. There were no significant differences (α = .01) between the soybean oil diet and the canbra oil diet for total red blood cell count, hematocrit, haemoglobin, reticulocyte count, leukocyte count and platelet count. The results of the study indicate no change in the oxygen carrying capacity of the blood and the functioning of the hemopoietic system of young college males fed diets in which soybean oil or canbra oil provided about 95 per cent of the fat calories.

The results of the present study indicate that the ingestion of 126 grams of canbra oil daily for 10 days has no deleterous effect on energy metabolism at rest or under physical work, serum lipid patterns or whole blood hematology of healthy, young college males.

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APPENDIX

Appendix Table 1

Cream of Wheat (1 serving)

Utensil: 1-8 oz. Pyrex dish

Method: Preheat oven 350° F.

1. Add the following ingredients to Pyrex dish:
   125 ml. boiling water
   20 grams Cream of Wheat
   0.5 grams salt
2. Stir.
3. Add 10 grams fat.[1]
4. Cook in oven 15 minutes.
5. Serve hot in dish.

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[1]Butter - Mixed Fat Diet; Soybean Margarine - Soybean Oil Diet; Canbra Margarine - Canbra Oil Diet.

Appendix Table 2

Rolled Oats (1 serving)

Utensil: 1-8 oz. Pyrex dish.

Method: Preheat oven 350°F.

1. Add the following ingredients to Pyrex dish:
   125 ml. boiling water
   30 grams rolled oats
   0.5 grams salt
2. Stir.
3. Cook in oven for 15 minutes.
4. Serve hot in dish.

Appendix Table 3

Scramble Egg Albumen Mixture (Yield 9 servings)

Method:

1. Pour 175 ml. cold water into blender.
2. Dust in 129 grams egg albumen and 9 grams skim milk powder.
3. Mix on slow speed.
4. Pour mixture in container and add:
   700 ml. cold water and
   9 drops yellow food colouring.
5. Mix well.
6. Store in refrigerator.

Appendix Table 4

Scramble Egg Albumin (1 serving)

Utensil: 1 porcelain small frying pan.

Method:
1. Weigh 100 grams egg albumin mixture (appendix Table 3) into aluminum measuring cup.
2. Heat frying pan (just hot).
3. Melt 10 grams fat[1] in frying pan.
4. Pour in egg albumin mixture.
5. Scramble egg (scrape spatula well).
6. Serve hot in fry pan.

---

[1]Butter - Mixed Fat Diet; Soybean Margarine - Soybean Oil Diet; Canbra Margarine - Canbra Oil Diet.

Appendix Table 5

Scalloped Potatoes (1 serving)

(1 - 6½ oz. package Idahoan scalloped potatoes is sufficient for 3 servings)

Utensil: 1 foil container 5" x 4" x 1½"

Method:

1. Preheat oven to 325°F.
2. Empty contents of paper package containing dry sauce mix into a sieve and sift out dehydrated onions and set aside. Keep the rest of the dry sauce mix separate.
3. Into a small foil container measure 10 grams liquid fat.[1]
4. Add 20 grams dry sauce mix and stir into a paste.
5. Add 239 ml. boiling water.
6. Add 2.0 grams dehydrated onion (sifted earlier). Stir to disperse fat-starch mixture and dissolve large lumps.
7. Add 40 grams dried potatoes. Stir.
8. Place uncovered in oven for 40 minutes. Serve at once.

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[1]Fat Mix[2] - Mixed Fat Diet; Crisco Oil - Soybean Oil Diet; Canbra Oil - Canbra Oil Diet.

[2]See Appendix Table 17.

Appendix Table 6

Spaghetti with Tomato Sauce (1 serving)

Utensil: 1 foil container 8" x 5½" x 2".

Method:

1. Place 10 grams liquid fat[1] in a small saucepan.
2. Stir in 2.0 grams cornstarch.
3. Add the following ingredients:

   2.0 grams finely chopped green pepper
   120.0 grams drained, canned tomatoes
   60.0 grams tomato juice (from can of whole tomatoes)
   16.0 grams tomato paste
   8.0 grams tomato sauce
   0.2 grams dehydrated onion flakes
   2.0 grams salt
   0.5 grams ground oregano
   0.5 grams dried sweet basil leaves
   0.5 grams black pepper
   0.2 grams garlic powder

   Bring to a boil slowly while stirring.

4. Reduce heat and simmer, stirring constantly for 10 minutes (or until all fat has been reabsorbed).
5. Pour contents of saucepan into foil container.
6. While tomato sauce is cooling, cook the pasta.
7. To prepare pasta:

   Bring 400 ml. water and 2 grams salt to a rolling boil in a small saucepan.

   Add 40.0 grams (dry weight) spaghetti pasta. Cook for 8 minutes (uncovered).

   Empty contents of saucepan into a sieve. Rinse pasta with cold water.

8. Add cooked spaghetti to cooled tomato sauce separating strands and mixing with the sauce.
9. Cool, cover (with foil lined container covers), label, freeze.

Appendix Table 6 (Concl'd)

To reheat: Preheat oven to 325°F.

Loosen edges of foil container.

Place frozen, covered spaghetti in oven for 30 minutes.

Remove cover and serve.

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[1]Fat Mix[2] - Mixed Fat Diet; Crisco Oil - Soybean Oil Diet; Canbra Oil - Canbra Oil Diet.

[2]See Appendix Table 17.

Appendix Table 7

Green Beans (1 serving)

Utensil: 1-8 oz. pyrex dish.

Method: 1. Add the following ingredients to saucepan

175 ml. boiling water

0.5 grams salt

2. Bring to the boil and add:

100 grams frozen green beans (weigh before freezing)

3. Cover and cook for 15 min.

Serve hot with 5 gm. fat.[1]

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[1]Butter - Mixed Fat Diet; Soybean Margarine - Soybean Oil Diet; Canbra Margarine - Canbra Oil Diet.

Appendix Table 8

Salads

Tossed Salad (1 serving)

Method: 1. Combine:

50 grams chopped lettuce

50 grams wedged tomato

2. Chill.

3. Serve chilled in individual pyrex dish.

Cole Slaw

Method: 1. Combine:

50 grams shredded cabbage

10 grams grated carrot

5 grams chopped green pepper

2. Chill.

3. Serve chilled in individual pyrex dish.

Appendix Table 9

Salad Dressing

Oil and Vinegar Dressing (1 serving)

Utensil: 1 - 3/4 oz. plastic creamer with plastic cover.

Method: 1. Weigh into individual container:

10 grams oil[1]

5 grams white vinegar

2. Shake well just before serving.

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[1]Corn oil - Mixed Fat Diet; Crisco oil - Soybean Oil Diet; Canbra Oil - Canbra Oil Diet.

Appendix Table 10

Sweet and Sour Pork (1 serving)

Utensil: 1 small foil container 5" x 4" x 1½".

Method:

1. Place the following ingredients in a small saucepan:

   25.0 grams TVP pork chunks
   15.0 grams brown sugar
   120.0 ml. unsweetened pineapple juice
   30.0 ml. water
   10.0 ml. soy sauce

   Bring to a rolling boil, cover and simmer with the lid on for 10 minutes.

2. Mix together:

   30.0 grams liquid fat[1]
   5.0 grams cornstarch until smooth.

   Add mixture to hot hydrated TVP mixture. Bring to a boil slowly, cook over medium heat stirring constantly until thickened.

3. Add 50.0 grams pineapple tidbits (drained) and 10.0 grams diced green pepper.

4. Cook an additional 5 minutes over medium heat stirring constantly.

5. Remove pot from heat.
   Add 5.0 ml. cider vinegar. Mix well.

6. Cool, then cover with foil lined container cover, label and freeze.

To reheat: Preheat oven to 325°F.

Remove foil lined cover.

Heat (covered with foil only) in oven for 40 minutes.

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[1]Fat Mix[2] - Mixed Fat Diet; Crisco Oil - Soybean Oil Diet; Canbra Oil - Canbra Oil Diet.

[2]See Appendix Table 17.

Appendix Table 11

Beef Stew (1 serving)

Utensil: 1 small foil container 5" x 4" x 1½".

Method: 1. Place the following ingredients in a small saucepan:

25.0 grams TVP beef chunks
100 ml. salt-free tomato juice
150 ml. water
0.2 grams dehydrated onion flakes
1 oxo beef cube
¼ tsp. kitchen bouquet
¼ tsp. worcestershire sauce

Bring to a boil, simmer with the lid on for 10 minutes.

2. Mix together:

40.0 grams liquid fat[1]
5.0 grams cornstarch untill smooth

Add starch mixture to hot hydrated TVP mixture.

3. Bring to a boil slowly, simmer for an additional 10 minutes, stirring constantly.

4. Empty contents of the saucepan into foil container.

5. Cool, then cover with foil lined container cover, label and freeze.

To reheat: Preheat oven to 325°F.
Weigh out 50 grams frozen peas** and 50 grams diced carrots.**

**Rinse peas and carrots with lukewarm water to get rid of excess ice and then weigh.

Heat frozen stew covered for 30 minutes.

Add peas and carrots. Stir to combine.

Cook in oven for an additional 20 minutes.

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[1]Fat Mix[2] - Mixed Fat Diet; Crisco Oil - Soybean Oil Diet; Canbra Oil - Canbra Oil Diet.

[2]See Appendix Table 17.

Appendix Table 12

Rice (1 serving)

Utensil: 1 foil container 5" x 4" x 1½".

Method: Preheat Oven 350°F.

1. Weigh 2.0 grams salt into foil container.
2. Add 100 ml. boiling water.
3. Add 30 grams raw rice and stir to distribute rice.
4. Add 15 grams liquid fat.[1] (Do not stir)
5. Cook in oven for 25 minutes.
6. Incorporate fat in to rice with subjects spoon just before serving.
7. Serve hot in foil container.

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[1]Fat Mix[2] - Mixed Fat Diet; Crisco Oil - Soybean Oil Diet; Canbra Oil - Canbra Oil Diet.

[2]See Appendix Table 17.

Appendix Table 13

Instant Mashed Potato (1 serving)

Utensil: 1 - 8 oz. pyrex dish.

Method: 1. Add the following ingredients to pyrex dish:

90 ml. boiling water

30 ml. skim milk

5 grams fat[1]

1.0 grams salt

2. Stir in 30 grams instant mashed potato.

Serve hot.

---

[1]Butter - Mixed Fat Diet; Soybean Margarine - Soybean Oil Diet; Canbra Margarine - Canbra Oil Diet.

Appendix Table 14

Cupcake (yield 32-27 grams cupcakes)

Method: Preheat oven 350°F.

1. Cream together:

   112 grams fat[1]
   200 grams white sugar

2. Add:

   1 tsp. vanilla essence
   ½ tsp. almond extract

3. Sift together:

   192 grams cake flour
   3 tsp. baking powder
   ½ tsp. salt.

4. Beat until foamy:

   80 grams reconstituted egg albumin (6 water: 1 egg albumin)

5. Fold in 50 grams sugar until egg mixture is stiff but not dry.

6. Add (alternately in small amounts) 244 grams fluid skim milk and flour mixture.

7. Fold in egg mixture using a wire whisk.

8. Divide evenly to make 32 cupcakes.

9. Bake at 350°F. in cupcake tins lined with aluminum foil cupcake liners.

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[1]Fat Mix[2] - Mixed Fat Diet; Soybean Margarine - Soybean Oil Diet; Canbra Margarine - Canbra Oil Diet.

[2]See Appendix Table 17.

Appendix Table 15

Raisin Oatmeal Cookie (Yield 36 - 27.5 gm. cookies)

Method: Preheat oven 400°F.

1. Mix thoroughly together:

   250 grams white sugar
   112 grams fat[1]
   100 grams reconstituted egg albumin (6 water: 1 egg albumin)

2. Sift together and stir in:

   192 grams all-purpose flour
   1 tsp. soda
   1 tsp. salt
   2 tsp. cinnamon

3. Stir in:

   160 grams rolled oats
   164 grams seedless raisins

4. Lightly grease baking sheet with fat mix.

5. Drop from spoon to make balls of 27.5 gm.

6. Place on lightly greased baking sheet about 2 inches apart. Bake until lightly browned, 8-10 minutes.

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[1]Fat Mix[2] - Mixed Fat Diet; Soybean Margarine - Soybean Oil Diet; Canbra Margarine - Canbra Oil Diet.

[2]See Appendix Table 17.

Appendix Table 16

Spicy Fruit Square (Yield 16-30 grams squares)

Utensil: 1 - 7½" x 7½" cake pan

Method: Preheat oven 350°F.

1. Cream together:

   200 gm. brown sugar
   64 grams fat[1]

2. Prepare 100 grams reconstituted egg albumin (6 water: 1 egg albumin)

3. Add 1½ tsp. vanilla essence to fat and sugar mix.

4. Toss:

   40 grams seedless raisins
   40 grams chopped candied cherries

   in a small amount of allowed flour.

5. Sift together:

   85 grams all-purpose flour
   1 tsp. baking powder
   ¼ tsp. salt
   ½ tsp. cinnamon

6. Gradually add dry ingredients to creamed mixture. Blend well after each addition.

7. Stir in fruits.

8. Lightly grease baking pan.

9. Pour batter into pan and bake at 350°F for 30 min.

10. Cool. Remove from pan and divide into 16 equal squares.

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[1]Fat Mix[2] - Mixed Fat Diet; Soybean Margarine - Soybean Oil Diet; Canbra Margarine - Canbra Oil Diet.

[2]See Appendix Table 17.

Appendix Table 17

Composition of Fat Mix[1]

Ingredients	Per Cent
Tallow	18.2
Crisco	45.4
Lard	36.4

[1]Fat in recipes weighed in liquid state.

Appendix Table 18

Analysis of Variance: Ventilation Rate

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	141.16	0.061	2.85	4.34
Replications (days)	4	10.74	0.003	2.62	3.86
Phase	2	9522.91	6.186	3.25	5.21
Diet	3	15.00	0.006	2.85	4.34
Phase X Diet	6	6.17	0.001	2.35	3.32
Residuals (error)	37	28480.33			
Total	55	38176.31			

Appendix Table 19

Analysis of Variance: Oxygen Consumption

Source of Variation	df	SS ($X10^2$)	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	49.39	0.09	2.85	4.34
Replications (days)	4	41.25	0.05	2.62	3.86
Phase	2	3113.60	8.20	3.25	5.21
Diet	3	32.83	0.06	2.85	4.34
Phase X Diet	6	2372.77	2.08	2.35	3.32
Residuals (error)	37	7027.67			
Total	55	12637.51			

Appendix Table 20

Analysis of Variance: Respiratory Quotient

Source of Variation	df	SS ($X10^2$)	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	1.90	0.60	2.85	4.34
Replications (days)	4	0.80	0.20	2.62	3.86
Phase	2	12.50	6.30	3.25	5.21
Diet	3	0.50	0.20	2.85	4.34
Phase and Diet	6	0.10	0.02	2.35	3.32
Residuals (error)	37	36.40			
Total	55	52.20			

Appendix Table 21

Analysis of Variance: Glucose

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	600.40	1.06	2.85	4.34
Replications (days)	4	949.26	1.26	2.62	3.86
Phase	2	2378.79	6.30	3.25	5.21
Diet	3	363.73	0.64	2.85	4.34
Phase X Diet	6	102.94	0.09	2.35	3.32
Residuals (error)	37	6986.80			
Total	55	11381.92			

Appendix Table 22

Analysis of Variance: Lactate

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	1710.80	1.08	2.85	4.34
Replications (days)	4	400.87	0.19	2.62	3.86
Phase	2	6979.70	6.59	3.25	5.21
Diet	3	141.02	0.09	2.85	4.34
Phase X Diet	6	114.96	0.04	2.35	3.32
Residuals (error)	37	19595.35			
Total	55	28942.70			

Appendix Table 23

Analysis of Variance: Pyruvate

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	2.66	2.78	2.85	4.34
Replications (days)	4	1.86	1.47	2.62	3.86
Phase	2	5.21	8.31	3.25	5.21
Diet	3	0.07	0.06	2.85	4.34
Phase X Diet	6	0.02	0.01	2.35	3.32
Residuals (error)	37	11.72			
Total	55	21.64			

Appendix Table 24

Analysis of Variance: Lactate/Pyruvate Ratio

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	69.31	0.20	2.85	4.34
Replications (days)	4	74.19	0.16	2.62	3.86
Phase	2	1388.12	6.00	3.25	5.21
Diet	3	37.06	0.11	2.85	4.34
Phase X Diet	6	49.93	0.07	2.35	3.32
Residuals (error)	37	4281.81			
Total	55	5900.42			

Appendix Table 25

Analysis of Variance: Glycerol

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	5.99	7.84	2.85	4.34
Replications (days)	4	7.31	7.31	2.62	3.86
Phase	2	4.17	8.19	3.25	5.21
Diet	3	1.54	2.02	2.85	4.34
Phase X Diet	6	1.86	1.22	2.35	3.32
Residuals (error)	37	9.42			
Total	55	30.29			

Appendix Table 26

Analysis of Variance: Serum Cholesterol

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	3871.69	207.66	8.89	27.67
Replications (days)	3	7845.69	48.10	6.09	14.98
Diet	1	231.13	4.25	5.32	11.26
Residuals (error)	8	434.93			
Total	15	12383.44			

Appendix Table 27

Orthoganol Comparisons: Serum Cholesterol

Comparison	df	SS	F-Value	F-Tabulated ($\alpha = .05$)	F-Tabulated ($\alpha = .01$)
1. Mixed Fat Vs. Canbra Oil and Soybean Oil Diets	1	1218.37	22.41	5.32	11.26
Residuals (error)	8	434.93			

Appendix Table 28

Analysis of Variance: Serum Triglycerides

Source of Variation	df	SS	F-Value	F-Tabulated (α=.050)	F-Tabulated (α=.010)
Subjects	3	6695.19	5.62	8.89	27.67
Replications (days)	3	3704.69	2.33	6.09	14.98
Diet	1	0.06		5.32	11.26
Residuals (error)	8	2779.56			
Total	15	13179.50			

Appendix Table 29

Analysis of Variance: Serum Lipid Phosphorus

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	1.06	3.53	8.89	27.67
Replications (days)	3	10.12	33.73	6.09	14.98
Diet	1	0.10	1.00	5.32	11.26
Residuals (error)	8	0.76			
Total	15	12.04			

Appendix Table 30

Analysis of Variance: Red Blood Cell Count

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	0.96	0.78	8.89	27.67
Replications(days)	3	3.36	2.73	6.07	14.98
Diet	1	0.02	0.006	5.32	11.26
Residuals (error)	8	3.30			
Total	15	7.64			

Appendix Table 3.1

Analysis of Variance: Hematocrit

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.05)	(α=.01)
Subjects	3	1.68	0.69	8.89	27.67
Replications(days)	3	70.53	29.02	6.09	14.98
Diet	1	0.28	0.35	5.32	11.26
Residuals (error)	8	6.44			
Total	15	78.93			

Appendix Table 32

Analysis of Variance: Haemoglobin

Source of Variation	df	SS	F-Value	F-Tabulated (α=.05)	F-Tabulated (α=.01)
Subjects	3	10.60	23.56	8.89	27.67
Replications (days)	3	0.79	1.76	6.09	14.98
Diet	1	0.08	0.53	5.32	11.26
Residuals (error)	8	1.19			
Total	15	12.66			

Appendix Table 33

Analysis of Variance: Reticulocyte Count

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	24.27	0.05	8.89	27.67
Replications(days)	3	1228.70	2.76	6.09	14.98
Diet	1	150.51	1.01	5.32	11.26
Residuals (error)	8	1189.26			
Total	15	2592.73			

Appendix Table 34

Analysis of Variance: Leukocyte Count

Source of Variation	df	SS	F-Value	F-Tabulated	
				(α=.050)	(α=.010)
Subjects	3	21.77	3.04	8.89	27.67
Replications (days)	3	34.23	4.77	6.09	14.98
Diet	1	1.71	0.72	5.32	11.26
Residuals (error)	8	19.08			
Total	15	76.79			