EFFECT OF DIETARY FATTY ACID COMPOSITION OF DIFFERENT LIPID SOURCES ON THE FATTY ACID COMPOSITION OF PORK FAT TISSUES: A NUMERICAL LITERATURE REVIEW

A thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Animal Science at Massey University, Palmerston North, New Zealand.

Viswa Teja Marella

Abstract

Based on the current database, in this dissertation attempts were made to investigate and summarize the effects of dietary Fatty Acid (FA) content of different lipid sources on the fatty acid composition of pork fat tissues. A total number of 84 related research publications were picked for the review, of which 23 articles were thoroughly studied and 17 were ultimately chosen for analysis based on defined criterion. All the 17 articles reported a strong correlation between dietary fatty acids and fatty acid in tissues of pigs, but their effect on increasing those FA in pig tissues was inconsistent and insignificant.

In the 17 articles selected for analysis, a total of 52 dietary treatments were extracted which reported FA composition of which 45 diets displayed FA composition in Sub-Cutaneous adipose tissue (SC) and 35 displayed FA composition in Longissimus Muscle (LM). Nine major lipid sources were identified in the selected 52 diets out of which 7 sources reported enough components in diet to carry out regression analysis, correlation coefficients and provided information to compare them. Majority of the diets selected had a Soya bean Oil (SBO) source (10) followed by Linseed Oil (LO) (7) and Animal Tallow (AT) (7). As there are (9) Special Oils (SO) made up of blends and different oil sources, which are less prevalent, they were grouped together to symbolize them.

Each lipid source proved to be the source of certain specific FA groups and they integrated those specific FA into fat tissues of pork, resulting in changes in FA composition. Animal Tallow (AT) diets resulted in the highest Saturated Fatty Acid (SFA) content in diets (42.03%) and Conjugated Linoleic Acid (CLA)- added diets resulted in the highest SFA content in fat tissues: SC (42.73%) and LM (45.35%). Both these lipid sources elicited most of SFA related changes in pigs' bodies. AT had better correlation values between the diets and SC (0.696), LM (0.613), while CLA- added diets had the highest regression intercepts for both the tissues: SC (95.27), LM (37.14) compared to other lipid sources.

Sunflower Oil (SFO) was the major source for Monounsaturated Fatty Acids (MUFA). Highest MUFA mean percentage in tissues: SC (48%) and LM (51%) was observed with SFO treatments followed by SO. Both the oils had highest mean percentage of MUFA in diets (39.3 % and 40.6 %) respectively. In comparison to all other diets, the sunflower oil diet had one of the greatest increases in regression equation intercept (30.1%) for SC, and the highest increase (46.89%) for LM.

Like SFA, the highest correlation between MUFA diet and SC is found in SFO diet (0.984) followed by SO diet (0.949). Similarly, greatest correlation between diet and LM is observed in the same diets (0.613), (0.370) respectively. SO diets and AT diets displayed higher MUFA SC percentage compared to LM percentage, whereas all other diets contradicted this, with higher MUFA percentage being observed in muscles but not fat tissue.

SBO, LO and Fish Oil (FO) were the best providers of Poly Unsaturated Fatty Acids (PUFA) among the lipid sources identified. FO diets had one of the highest PUFA mean percentage (46.4%), less than diets like SFO (46.8%), SBO diet (54.72 %) and LO diet (56.01%). FO had slightly higher PUFA mean SC than SFO (20.38 % and 19.25 %). Though having lesser mean PUFA diet content compared to SBO and LO, FO had greatest increase in regression intercept (20.11%) for PUFA SC indicating its effective dominance in incorporating more PUFA into SC than any other diets.

Highest individual PUFA content in diet is prominent in SBO diets (70.9%) indicating it as one of the best sources for PUFA. SBO also had the second highest mean PUFA in diets (54.72%) next to LO diet (56.1%). A similar trend is followed in the regression intercept of PUFA LM and PUFA SC with these diets. Though having lesser PUFA diet percentage, SBO displayed greatest mean percentage of PUFA SC and PUFA LM (27.41 and 20.99).

LO diet had the highest mean percentage PUFA diet (56.01) among all the dietary treatments. Despite having highest PUFA percentage diet, LO had lesser mean percentage of PUFA SC (24.75) and PUFA LM (14.24) compared to SBO (27.41 and 20.99) respectively. LO had greater increases in regression intercept of the tissues with diets compared to SBO.

SFA and MUFA can be synthesized in the bodies of pigs but not PUFA, thus they are known as essential FA, and they should be supplied to the animals through diet alone. Though having greater PUFA mean percentage in diet and tissues, SBO and LO didn't increase n-3 PUFA such as Eicosapentaenoic Acid (EPA), Docosahexaenoic Acid (DHA) and Docosapentaenoic Acid (DPA) which are only found in FO, and which are also important in terms of human health.

Keeping n-3 PUFA aside, it is evident from the review that plant-based lipid sources like SBO and LO can increase overall PUFA content better than FO and they are economical to use at farm level. Moreover, with increased commercial fishing we are causing irreparable damage to the oceans and ecology, which must be mitigated, and more agricultural practices must bepursued to reduce our carbon footprint. Therefore, using plant-based lipid sources as an alternate to FO is advised and future research should focus on developing better n-3 PUFA sources to lessen our reliance on fisheries to obtain these FA.

Acknowledgements

First and foremost, I would like to express my gratitude to Prof. Patrick Morel, my chief research supervisor, for his guidance and support throughout my Masters at Massey University in New Zealand, and for ensuring that my work progressed at a steady pace. His open-door policy for meetings allowed for quick clarification of doubts, especially during the pandemic and country's lockdown. I am indebted to his motivational words and encouragement which boosted my morale and gave me confidence in this work.

I would also like to acknowledge the Animal Science department faculty, Library staff in Massey University for their engagement in the study.

I thank my beloved parents and brother, who were with me at every step of this journey, even though they are thousands of miles away in India. I would also thank my Massey University friends and peers, who have become like family members here. Finally, I thank myself for choosing the study of Animal Sciences and not giving up in the weakest moments of life.

List of Tables

List of Figures

List of abbreviations

ALA	Alpha Linolenic Acid
AT	Animal Tallow
BF	Back Fat
CLA	Conjugated Linoleic Acid
DHA	Docosahexaenoic Acid
DPA	Docosapentaenoic Acid
EPA	Eicosapentaenoic Acid
FA	Fatty Acids
FO	Fish Oil
GLA	Gamma Linolenic Acid
IMF	Intramuscular Fat
LA	Linoleic Acid
LM	Longissimus Muscle
LO	Linseed Oil
MUFA	Monounsaturated Fatty Acids
n-3	Omega-3
n-6	Omega-6
PUFA	Poly Unsaturated Fatty Acids
SBO	Soya Bean Oil
SC	Sub-Cutaneous Fat/ Adipose tissue Fat
SFA	Saturated Fatty Acids
SFO	Sunflower Oil
SO	Special Oils

1 CHAPTER 1

1.1 General Introduction

The ever-increasing needs of modern lifestyles, goaded by quick targets, stress, health difficulties, and disorders, all compel the development of innovative solutions to address necessities, particularly in food supply and its security. As a result, food scientists have spent a lot of time in recent years exploring specific nutrients that can improve human health or reduce diseases that are growing more common in modern society. In addition to their essential dietetic constituents, functional foods or meals having nutrients that have a favorable impact on human health are increasingly appearing in daily nutrition requirements.

High levels of saturated fatty acids are believed to raise the risk of heart diseases, making meat consumption unsuitable for health reasons. Polyunsaturated fatty acids (PUFA), which lowers blood cholesterol, appear to be found at low levels in meat, especially those of the n-3 series with health benefits (Sciences, 1994).

Many researchers have thus looked for ways to alter the composition of meat fatty acids, primarily through the feeding of PUFA plant sources, particularly oil seeds.

In the study of dietary impact on carcass fat content in pigs, other factors such as gender, sex, management, feed level, climate, slaughter weight and potential interactions between these factors should also be considered. The diet can affect the quality of meat by providing a different combination of reactive ingredients that affect oxidative stability (shelf life) and flavor components and gives us the freedom to experiment with different lipid sources.

The composition of fatty acids of the muscles and the adipose tissues of a pig can be significantly altered, since pig is a single stomach animal, and dietary fatty acids are metabolized intact in the gut and integrated into the tissue lipids.

It is also widely established that the amount and the fatty acid composition of the diet affects the quality of carcass fat in pigs. As fat is also of interest with regards to the fresh taste of the meat, recent research mainly focuses on the fatty acid composition of intramuscular membranes and theirfat content.

However, not many researchers had focused on lipid source effects on pork fat tissues in a comparable manner. Though meta-analysis for specific lipid sources had been previously studied, a gap in our literature can be found studying, investigating, and compiling dietary effects of commonly used lipid sources on fat tissues of pigs around the world, which became the main objective of this review.

2 CHAPTER 2: Literature Review

2.1 Benefits of pork consumption

Pork is one of humanity's most essential meat sources. The amount of PUFA in intramuscular fat in pork is higher than in beef and is more easily controlled by dietary variables Wood & Enser, (1997), making it easier to qualitatively adjust human dietary fat intake. According to Coates & Ayerza, (2009), small increases in long chain n-3 PUFA intake from frequent consumption of enhanced pork can lower cardiovascular risk.

Changing a pig's diet is an effective way to increase n-3 PUFA content while lowering the n-6/n-3 ratio. The following are the key benefits of producing pork that is high in n-3 PUFA: (1) Pork accounts for more than half of all meat consumed by humans; it is more traditional and less expensive than fish or fish products Givens & Gibbs, (2008) (2) Because dietary fatty acids are quickly absorbed into pig muscle and fat tissues, supplementing diets with n-3 PUFAs such as fish oil, fishmeal, or linseed is far more effective than in ruminants. In ruminants, microbial bio-hydrogenation reduces polyunsaturated fatty acids (PUFA) to monounsaturated fatty acids (MUFA) and saturated fatty acids (SFA) in the rumen, with only a tiny fraction escaping to be incorporated into tissue lipids Nuernberg et al., 2005; Wood et al., (1999). (3) Although n-3 PUFAs are abundant in swine liver, muscle, and adipose tissue, few people believe that pigs have a nutritional need for them, making pigs potentially perfect carriers for delivering them to humans (4) Because dietary fatty acids may be taken without hydrogenation modifications and integrated unmodified into tissue lipids, the fatty acid composition of pig lipids can be considerably altered by modifying the appropriate oil source in their feed.

2.2 Importance of diet

Pigs fed standard compound feed produce “unhealthy” meat due to an imbalanced n-6: n-3 ratio. This is due to the fact that the composition of polyunsaturated fatty acids in pig feeds has a consistent effect on the PUFA composition of meat Nguyen, Nuijens, Everts, Salden, & Beynen, (2003). However, Koch, Pearson, Magee, Hoefer, & Schweigert, (1968) and Leszczynski et al., (1992) found that LM was less affected by diet than back fat. In fact, diet has a weak influence on intramuscular fat Kouba & Mourot, (1999); Warnants, Van Oeckel, & Boucque, (1999). This may be due to lower deposition of absorbed fat in muscle tissue Vernon, (1992) or due to greater proportion of membrane lipids in intramuscular fat which contains high quantities of PUFAs for structural reasons, that are relatively insensitive to dietary variations.

Nevertheless, a linear relationship between PUFA intake and the PUFA content of both intramuscular and back fat is generally reported for pigs, although the efficiency of PUFA incorporation differs in the two tissues Van Deckel, Casteels, Warnants, Van Damme, & Boucque, (1996).

A clear effect on the concentration of lipid weight of the various animal tissues was altered by the fatty acid composition in the diet. Adipose tissue, rather than muscle, was the best place to store dietary fatty acids. Backfat is also the most vulnerable to changes through dietary composition.

Therefore, it can be concluded that, by judicious selection and supply of diet ingredients for pigs, pork products can be produced with lower saturated fats and alteration FA profile is possible to meet the modern requirements for human nutrition.

2.2.1 Importance of PUFA in diet

Like other species, pigs cannot synthesize Linoleic Acid (LA C18:2n-6) and Alpha Linolenic Acid (ALA C18:3n -3) which are essential fatty acids. Therefore, these parent fatty acids must be included in the diet. Other essential fatty acids of the n-6 and n-3 families are produced by desaturation and chain elongation responses, which can be synthesized in the organism.

The n-3 PUFAs are polyunsaturated fatty acids that contain 2 or more double bonds. The location of the double bond closest to the methyl terminal of the acyl chain of the fatty acid is designated as n-3. Counting the methyl carbon as carbon one, this double bond exists on carbon 3 in all n-3 fatty acids (Calder, 2013).

n-3 PUFA were found to be crucial for protection against many disorders and were first discovered in the early 1970. The most significant types of n-3 fatty acids that have a role in the body include α-linolenic (C18:3n-3; ALA; the simplest n- 3 PUFA); eicosapentaenoic acid (C20:5 n-3, EPA). Of the n-3 PUFAs, ALA is important to humans, but it must be derived from the diet because ALA is not synthesized *de novo*. Once adequate ALA has been supplied through diet, EPA, DPA and DHA can be synthesized by pig.

n-3 polyunsaturated fatty acids (n-3 PUFA) are key components of cell membranes that regulate membrane fluidity, eicosanoid production, cell signaling, and gene expression among other things Jump, (2002). They protect the cardiovascular system and reduce the risk of atherosclerosis, cancer, and hyperlipidemia, as well as stimulating the anatomical and functional development of the infant brain. Human health benefits from increasing n-3 PUFA intake and balancing the n-6/n-3 ratio in the body.

Fish is currently the most important source of n-3 PUFA for human consumption, however global fish stocks are depleting and cannot supply a long-term source of n-3 PUFA.

Furthermore, chemical pollutants (such as mercury) in fish can be toxic to consumers, and the odor is unpleasant Bourdon et al., 2010; Mahaffey, Clickner, & Jeffries, (2008). Fish oil is expensive and supplementing with it raises the danger of taste taints and rancidity in meat Wood et al., (1999).

Whole seeds such as Flaxseed, walnuts, seeds, or oil from Echium plantagineum, soybeans, olives, and cauliflower are examples of plant sources that are easily available, renewable, and affordable. The delta-6 desaturase enzyme needed to synthesize ALA is not found in animals and humans but only in plants. The major downside, however, is that diets of plants origin alone are not enough for human nutrition Toppe, (2011). Biosynthetic food is also a possible source.

2.2.2 Importance of n-6: n-3 ratio

Excessive consumption of n-6 PUFA, particularly linoleic acid (18:2 n-6), has been linked to a variety of ailments in humans, including cardiovascular disease, cancer, and inflammatory and autoimmune diseases Czernichow, Thomas, & Bruckert, (2010).

The n-6/n-3 ratio in typical western diets is 10–30:1, with significantly greater levels of n-6 Hibbeln, Nieminen, Blasbalg, Riggs, & Lands, (2006).

The current high amount of n-6 PUFA in the human food supply is a concerning factor because these fatty acids can prevent ALA from being converted to EPA and DHA. Furthermore, diets high in n-6 PUFA cause an increase in amino acid content in membrane phospholipids, which leads to eicosanoids overproduction, aggravating arterial and other chronic diseases Simopoulos, (2002b). As a result, a proper n-6/n-3 ratio in the diet is critical Simopoulos, (2002a).

To summarize, increasing n-3 PUFA content and decreasing the n-6/n-3 ratio in pork is a practical way to meet public health requirements for improving human nutrition and health.

2.3 Effects of dietary alteration on fatty acid composition in pigs

2.3.1 Fat deposition

Fat deposition varies from synthesis to mobilization, which relies on the intake of energy and the ingestion of essential nutrients. In the pig, lipid synthesis predominantly occurs in fatty tissue, with the primary precursor being glucose. Christensen & Goel, (1972).

The most common fatty acids in pigs' adipose tissues are the C16:0, C18:O and C18:1 long-chain fatty acids that are synthesized in tissues Jakobsen & Thorbek, (1991). C12:O and C14:O are stored in fat depot if they are present in the feed but only to a small degree Christensen, (1962). This demonstrates that a variety of dietary fatty acids can be selected to control the fat depot's fluidity. In fat depots of muscle and adipose tissue, the arachidonic acids (C20:4n - 6) and other C20-C22 are contained at concentrations so small as not to be detectable with regular gas-liquid chromatography. Linoleic acid, and linolenic acids of the n-6, or n- 3 family are also present in similar low ranges.

2.3.2 Carcass fat firmness

We can adjust the fatty acid composition of the fat depots by adjusting the fatty acid composition of dietary fat, thus changing the end fat and meat products. Several experiments demonstrated that saturated fatty acids (C12:O-C l8:O) had a positive influence on the properties and cohesiveness of carcass fat tissue, whereas monounsaturated acids (C16:1, C18:1) and especially polyunsaturated fatty acids (Cl8:2, C18:3) had a negative influence.

2.4 Factors affecting fatty acid composition through dietary alteration

2.4.1 Molecular Lipid structure

Dietary effects on PUFA content in intramuscular lipids and lipid fractions were generally less pronounced than those found for BF. Miller, Shackelford, Hayden, & Reagan, (1990) found a lower response on fatty acid composition by dietary fat in intramuscular fat (IMF) (both outer and inner layers) than in subcutaneous fat (considering both layers together).

This difference could be due to the I.M. fat tissue's slower deposition rate Vernon, (1992) and the presence of complex structural lipids in large quantities in I.M. fat than in other fat depots like BF, as the higher the concentration of polar lipids, the lower is the expected response.

Muscle phospho lipid contains more PUFA (18:2(n-6) and 20:4(n-6) than sub cutaneous fat depot and is less easily influenced by diet. LA and ALA were incorporated into I.M. fat less efficiently than BF in a study by Warnants, (1996).

Koch, Parr, & Merkel, (1968) found that 18:2(n-6) is preferentially deposited in BF over other fatty acids.

2.4.2 Anatomical location of fat tissues

The degree of unsaturation of fatty tissue in swine decreases from external to internal tissues, according to an earlier study by Thompson & Allen, (1969). The low to high unsaturation gradation follows the series: internal fat (omental and perirenal, etc.), intramuscular fat, inner subcutaneous layer, middle subcutaneous layer and outer subcutaneous layer, Villegas, Hedrick, Veum, McFate, & Bailey, (1973). According to Dean&Hilditch, (1933), this gradation can be explained by a possible adaptation of adipose tissue to temperature in order to maintain an adequate physical fluidity of lipids in various fat tissues, resulting in an increase in the melting point of fat from subcutaneous to internal locations.

2.4.3 Enzyme activity

The fatty acid profile differs depending on the location of fat tissue, most likely due to differences in enzyme activity. Intramuscular fat had the highest unsaturation, owing to increased activity of the delta-9 desaturase enzyme, followed by outer and inner subcutaneous backfat Daza et al., (2017).

2.5 Targeted fat tissues

2.5.1 Intramuscular Fat / Longissimus Muscle: -

The amount and structure of dietary fat, *de novo* fatty acid synthesis, conversion rate to other fatty acids and metabolites, and the proportion of oxidation for energy consumption all influence PUFA content in any tissue.

The overall PUFA content of the meat was not significantly changed by the PUFA content of the diet. Because dietary polyunsaturated lipids are deposited in body lipids, but fat synthesized by the animalis more saturated. The unsaturation of the animal's fat is positively associated to the carcass lean content Girard, Bout, & Salort, (1988). As a result, in Van Deckel et al., (1996) investigation, they were able to achieve a rather high amount of linolenic acid incorporation as they used lean pigs.

The amount of IMF in the muscle determines the fatty acid composition of IMF. SFA ($r = 0.39$; $P<0.001$), MUFA ($r = 0.65$; $P <0.01$), and PUFA content ($r = -0.78$; $P<0.001$) were all strongly linked with IMF levels. Higher IMF levels are associated with lower C18:2n-6 content ($r= -0.83$; $P<0.001$). This might be due to the fatty acid composition mismatch between muscle phospholipids and neutral lipids. Cameron & Enser, (1991) observed that when the IMF concentration increased, PUFAs were rapidly diluted by SFAs and MUFAs.

The quantity of phospholipids in muscle tissue that are rich in PUFAs remains rather constant, but neutral muscle lipids, primarily SFAs and MUFAs, increase as IMF content rises.

The longissimus muscle is also less sensitive to PUFA incorporation in bacon, according to Koch et al., (1968).

2.5.2 Subcutaneous Adipose Tissue

In an experiment by López-Bote, Isabel, & Daza, (2002) dietary treatment had the most pronounced effect on C18: 1 (n-9) and C18: 2 (n-6) concentrations in the inner backfat layer. This was expected because diets were designed to provide a wide range of concentrations of these two fatty acids while keeping the dietary concentrations of the remaining fatty acids relatively constant.

However, there was no effect of dietary fat source on C18:1 (n-9) and total MUFA concentration in the outer backfat layer, indicating that dietary treatment-induced changes in outer backfat layer composition are less dependent on fatty acid deposition and are more likely influenced by metabolic regulation of fatty acid accumulation elongation, desaturation, etc.

When pigs were fed diets containing up to 10percent fat, Koch et al., (1968) noticed a faster change in the fatty acid pattern in the inner layer of BF than in the outer layer as a result of changing dietary fat source. Similarly, Leymaster & Mersmann, (1991) concluded from their experiment that the middle BF layer, which corresponds to the inner layer of BF when pigs only have two layers of BF, was the most dynamic, with the highest lipogenic activity. In the current study, which used low-fat feeds, the higher lipogenic activity of the inner layer compared to the outer layer resulted in more *de novo* synthesis of SFA and MUFA and, as a result, a lower PUFA content.

3 CHAPTER3: Materials and methods

Animal Care and Use Committee approval was not required for this study because the data were obtained from an existing database.

3.1 Literature search

A systemic literature search was carried out using journals, book articles and abstracts from CAB Abstracts (ISI), web search engines like google scholar and web of science to identify research articles published between January 1990 and October 2018. The structured strategy included the following keywords applied as follows: “dietary influence” OR “pig” AND “n-3 PUFA” “MUFA” “SFA” OR “Omega 3” OR “linseed” OR “fish oil” AND “fatty acids composition”. A manual review of the reference list of the selected articles was conducted to identify additional articles for possible inclusion. Additional studies were identified from the reference lists of retrieved articles.

3.2 Study selection

To be included in the review the studies needed to satisfy the following criteria: (1) data collected from January 1990 up to October 2018; (2) English, French, Spanish or Italian languages; (3) study carried out in pigs from about 25 to 160 kg of live weight (LW); (4) studies should report at least two categories of SFA, MUFA, PUFA in both diets and tissues analyzed; (5) studies assessed both control and supplemented diets or comparison done among different diets; (6) study reported fatty acid percentages of Longissimus thoracis et lumborum (LTL) muscle and/or adipose tissue; (7) studies should also report fatty acid percentages(> 75%) individually or as a whole group . Our main goal is to determine the extent to which diet can influence fatty acid concentrations in muscle and adipose tissue, as well as the magnitude of its effect on fat depots in the chosen tissue.

Table 3.2.1 Summarizing study selection and filtering process

	n
Total articles selected	84
Papers studied for review	23
Papers selected for final review	17
Articles excluded	61
Total Diets	52

Majority of studied articles selected had to be excluded for not following the above criteria mentioned (table 3.2.1). Furthermore, out of 23 articles studied, 17 of them fulfilled all our criterion, 6 of them reported< 75% FA in our parameters (diet, SC and LM). Hence, they didn't make it out for final review.

Considering the restricted number of trials, we included in this numerical review animals with average initial weight of 49.4 kg (25 to 85 kg LW) and average final weight of 98.4 kg (from 50 kg to 160 kg LW). Dietary Fatty acid supplementation of included studies ranged from 30 to 103 days. Growth performances (average daily gain, average daily feed intake) were not evaluated due to the inadequate number of results. Some studies reported dietary comparisonswhich were not relevant to this study, or if there were more than one comparison group, only the results addressing the objectives of this study were extracted. The outcomes evaluated were the fatty acid composition of LTL muscle and subcutaneous adipose tissue. The lipid extraction methods were not considered for the restricted results available.

3.3 Data extraction

A database was created, including detailed description of each reference: author's name, publication year, animals used (gender, breed, weight), control and experimental diets (including description of n-3 fatty acids), source and dose of diets, duration of feeding, statistical analyses (mean value and averages) and fatty acid composition of Longissimus thoracis et lumborum (LTL) muscle and/or adipose tissue. Lipid extraction method was not considered.

Table 3.3.1 Summarizing final count of treatments selected for each of the major parameter

Fatty acid Group	Diet	Subcutaneous fat	Longissimus
Saturated Fatty Acids	52	45	35
Mono Unsaturated Fatty Acids	52	45	35
Poly Unsaturated Fatty Acids	52	45	35

Studying 52 different diets in articles, we found FA percentage in diet for all of them. 45 diets displayed FA percentage in subcutaneous fat tissue and only 35 of them presented percentage for longissimus muscle (Table 3.3.1).

Table 3.3.2 Types of lipids and their presence in different dietary treatments.

Serial. No.	LIPID SOURCE	NUMBER OF DIETS (n=52)
1	Animal Tallow (AT)	7
2	Fish Oil (FO)	6
3	Sunflower Oil (SFO)	4
4	Conjugated Linoleic Acid (CLA)	5
5	Soya bean Oil (SBO)	10
6	Special Oils (SO)	9
7	Linseed oil (LO)	7
8	Marine Algae	2
9	Peanuts	2

Majority of the diets selected had a soya bean oil source followed by linseed oil and tallow (Table 3.3.2). Since special oils is made up of blends and oil sources which are less prevalent, they have been grouped together to represent this category. Marine algae and peanut sources were presented with their percentage, although comparison could not be made among them because of the small sample size (2).

Table 3.3.3 Prevalence of individual FA in all selected diets.

Fatty Acids	No. of diets present in
C 14:0 (MYRISTIC)	38
C 16:0 (PALMITIC)	47
C 18:0 (STEARIC)	45
C 20:0 9 ARACHIDIC)	16
C 16:1-CIS-9 (PALMITOLEIC)	36
C 18:1 -CIS-9 (OLEIC)	47
C 20:1-CIS-11 (EICOSENOIC)	18
C 18:2n-6 CIS (LINOLEIC)	47
C 20:2-CIS (EICOSADIENOIC)	18
C 20:3-CIS (EICOSATRIENOIC)	18
C 20:4-CIS (ARACHIDONIC)	25
2C 20:5-CIS (EICOSAPENTAENOIC ACID EPA)	25
C 22:5 n-3 (DPA)	16
C 22: 6-CIS (DOCOSAHEXANOIC ACID DHA)	25
C 18:3 n-3 CIS-9,12,15 (α-LINOLENIC)	39
TOTAL SFA	58
TOTAL PUFA	58
TOTAL MUFA	58

Total FA groups were directly displayed in some articles, whereas for some articles they had to calculated by summing individual FA of the respective group (SFA, MUFA, PUFA). Table 3.3.3 shows the highest individual FA prevalent among the studies were C 16:0, C 18:1-CIS-9 and C 18:2n-6CIS (LA) each belonging to separate group. They were followed by C 18:0, ALA and C 16:1- CIS-9 indicating next highest FA in their respective groups. Long chain PUFA remained least prevalent FA among other groups indicating they are least studied/ difficult to obtain.

3.4 Statistical analysis

Microsoft Excel was used to create data frame (author, FA groups in diet, SC and LM) and to create figures plotting FA percentage input through diet and examining the response in tissues. It was also used to calculate averages and totaling individual FA to their respective groups.

The inputs for this review were statistical analysis results reported in literature means or difference in means, standard error/standard deviation, R-SQ values, regression intercept and slope. P-values were not displayed because majority of the papers only reported significant effect of diet in incorporating its FA percentage with some of the long chained PUFA alone and not in relation to SFA and MUFA and in some instances even LA and ALA. Similarly, R-SQ values were always inconsistent and lower indicating there is no evidence that X (independent/ predictor variable) in our case diet can't explain the variance of FA percentage caused in Y (dependent/ response variable), in this case the fat tissues SC and LM. This is acceptable in our case since we only tried to find the effect of lipid type on rate of incorporation of FA into fat tissues and each author in their experiments used different diets with no standard percentage of FA.

Regression analysis was done between FA percentage of dietary treatments in relation to FA percentage of LM and SC using Minitab for all lipid sources. Correlation co-efficient were also calculated in similar fashion using same software. Scatter plots were also created to explain FA groups as whole.

4 Chapter 4: Results and Discussion

Results of the different lipid source on FA percentage of diet, SC and LM are discussed with the help of the following statistics table and figures. They'll be summarizing their key effects and any deviation from previously published results and visualize the trend of FA incorporation in pork tissues by different lipid sources used in those publications. Each lipid source will then be presented with information discussing the individual changes in FA profile observed in SC and LM concurrently brought out by diet. Additional information like changes in FA ratio, molecular lipid structure, enzyme activity, anatomical location of tissues is provided for certain lipids toemphasize the lipid source effect on FA concentrations will be discussed. Hence for easier and clearer understanding of tables and figures in this section, those ending with 1 represents SFA and 2, 3 representing MUFA and PUFA respectively. Middle ascending numbers indicating lipid types which follow the sequence of AT, FO, SBO, SFO, LO, CLA, SO. Therefore, results will be presented for SFA first, then discuss lipid source changes in this FA group, then MUFA, PUFA and so on.

Saturated Fatty acids

1. **Animal Fat/ Tallow (AT)**

Table 4.1.1 Summarizing statistical values of SFA in AT diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression Intercept	Regression slope	R-SQ (%)	Correlation
SFA diet	7	42.03	7.88	29.67	52.92				
SFA sc	6	36.96	6.53	30.16	47.04	13.12	0.5546	48.4	0.696
SFA lm	5	36.51	4.55	30.76	42.16	21.61	0.3670	37.54	0.613

sc = subcutaneous fat; lm = longissimus

All lipid sources displayed an increase in mean percentage of SFA in longissimus muscle compared to subcutaneous adipose tissues except for the animal tallow diet which had similar mean

percentage for both tissues meaning carcasses with uniform overall SFA percentage (Tables ending with 1). In Table 4.1.1 we can also notice a decrease in the mean percentage between SFA percentage of diets and fat tissues for animal tallow diet alone, this can be attributed to the high percentage of SFA in animal fat with mean of 42% with the next highest percentage of 25 found in fish oil. This results clearly shows that tallow diets are a rich source for SFA.

This also proves a critical point that SFA percentage in tallow diet is inversely proportional in the tissues and all other diets had an elevated mean percentage in tissues. This inverse relationship might be due to low solubility and absorption of increased SFA in tallows, resulting in slower transport in cells and a lower degree of incorporation into lipids. Another factor is the rapid conversion of SFA to MUFA, which accelerates over time. The latter observation could also be due to the *de novo* synthesis Warnants, (1999).

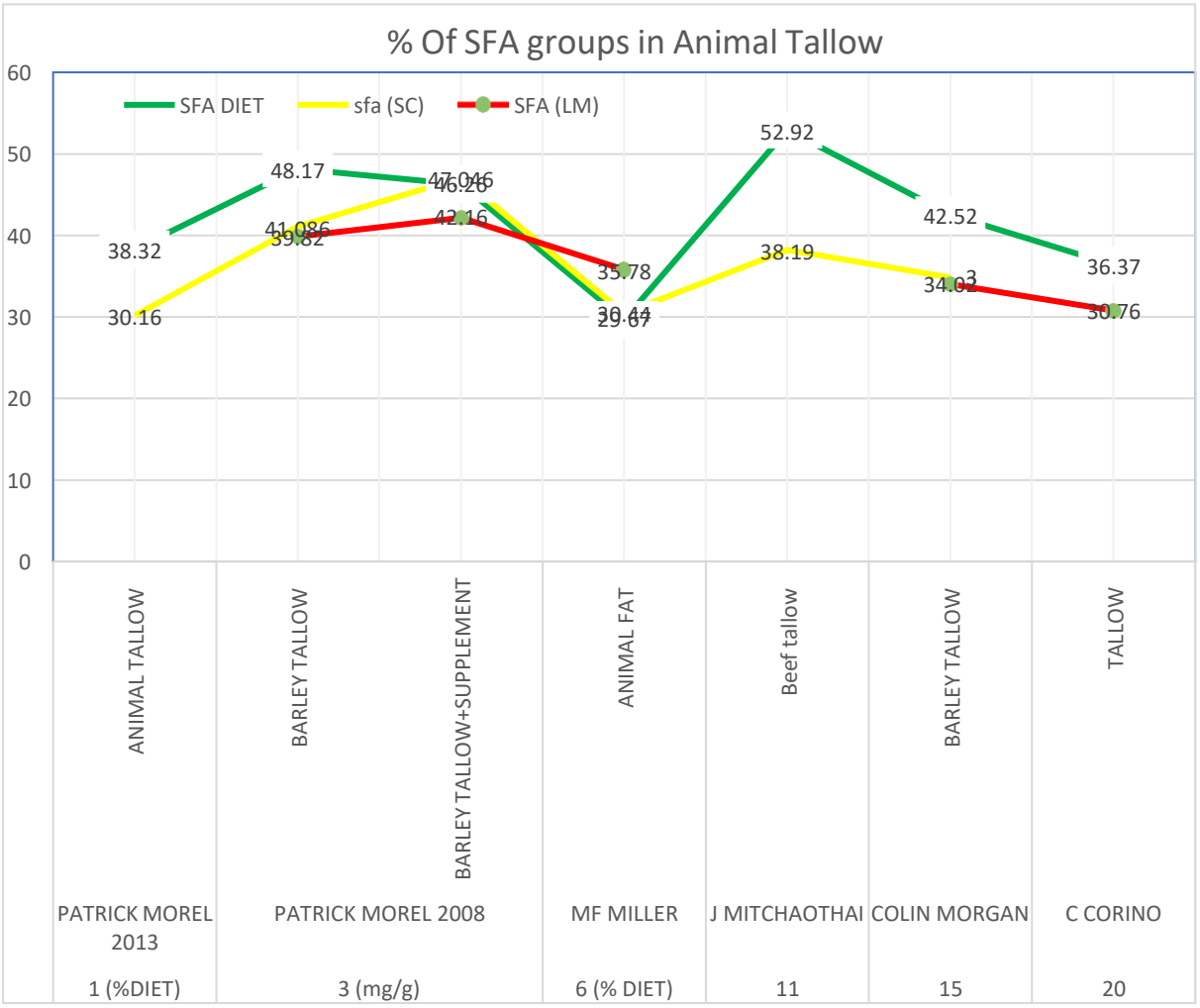

Figure 4.1.1 SFA (percentage) in fat tissues SC and LM compared to their diets in pigs fed AT.

Summarizing Figure 4.1.1, SFA percentage of diet remained highest in 6 out of 7 articles studied indicating tallow diets are dominant in them. SFA percentage of SC was greater than LM whenever they were presented together except for results from Miller et al., (1990) who reported higher SFA percentage in LM. An inconsistent pattern can be witnessed, and no direct relationship of diet SFA percentage on SC and LM can be established.

Changes in fatty acid profile

As we already know that AT has the highest SFA percentage in diets, it's bound to bring out more SFA oriented changes in the fat tissues. Increased SFA, MUFA and decreased PUFA especially n-3, n-6 concentrations are found in adipose tissue or subcutaneous fat (Corino et al., 2002; Mitchaothai et al., 2007; Morel, Leong, Nuijten, Purchas, & Wilkinson, 2013; Morgan, Noble, Cocchi, & McCartney, 1992). Increased SFA, MUFA and decreased PUFA especially n-3, n-6 are found in longissimus muscle Morel et al., (2013). In this experiment, Pigs fed an animal-based diet (AT) had more palmitic, palmitoleic, and cis-vaccenic acids and less linoleic, α-linolenic, ecosatrienoic acids, and DPA in their longissimus muscle than those fed a plant-based (SBO) diet.

The amount of saturated fat in the supplemented plant-based diet (POS) increased when soybean and linseed oil were replaced with tallow (PTS) (myristic and palmitic) Morel et al., (2013) indicating that mid trial replacement of diet with AT increases SFA concentration.

In both subcutaneous and intramuscular adipose tissue, the percentage of total saturated fatty acids (14:0, 15:0, 16:O, and 18:O) decreased from approximately 40% in the control to approximately 31% in AT, which was highest comparing to other lipid sources used in that experiment Miller et al., (1990).

Diet 1 (AT) had larger levels of Palmitic acid (16:0) in the outer and inner backfat than experimental diets 2, 3, and 4 (CLA added diets) ($P < 0.05$ and $P < 0.001$, respectively) (Morgan et al., 1992). These effects are mostly due to tallow having a larger quantity of palmitic acid, with carcass fat mirroring dietary fat composition Wood, (1984).

Only the inner backfat sample revealed treatment effects of stearic acid 18:O, with AT having a higher level than the other treatments ($P < 0.001$), because tallow contains more stearic acid than SBO Morgan et al., (1992).

FA ratio

Wood et al., (2004) proposed that the recommended PUFA:SFA ratio for the health of humans consuming pork to be> 0.4, which means that pork from pigs on AT diet was too low for SC and LM (0.290 and 0.162) respectively Morel et al., (2008).

The AT treatment resulted in LA: ALA ratio that exceeded the desired maximum by more than 4.5 times Morel et al., (2008). It should be noted that the linoleic to linolenic acid ratio is simply suggestive of the overall ratio of n-6 to n-3 fatty acids, and the predominant long chain n-3 fatty acid is DHA Ruxton, Calder, Reed, & Simpson, (2005), which was at least 3 times higher in the animal diet group than the plant diet group for all three tissues.

PUFA:SFA ratio was greater for plant diets because of their decreased SFA, MUFA and increased PUFA Morel, McIntosh, & Janz, (2006). n-6: n-3 ratio was acceptable only for animal diets due to their highest DHA concentrations in selected tissues.

All polyunsaturated to saturated fatty acid ratios were higher than the objective of 0.45, apart from backfat samples from pigs on dietary tallow. Even the muscle sample ratios were more than 0.45 on this diet Morgan et al., (1992).

2. Fish oil (FO)

Table 4.2.1 Summarizing statistical values of SFA observed in pigs fed FO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
SFA diet	6	25.36	3.47	18.60	28.10				
SFA sc	6	37.07	4.95	29.40	41.42	25.78	0.4452	9.71	0.312

sc = subcutaneous fat.

Next to AT, Fish Oil had highest SFA mean diet (Table 4.1.1 and 4.2.1). FO also had secondhighest regression intercept for SFA SC only next to CLA additive diets (Table 4.6.1)

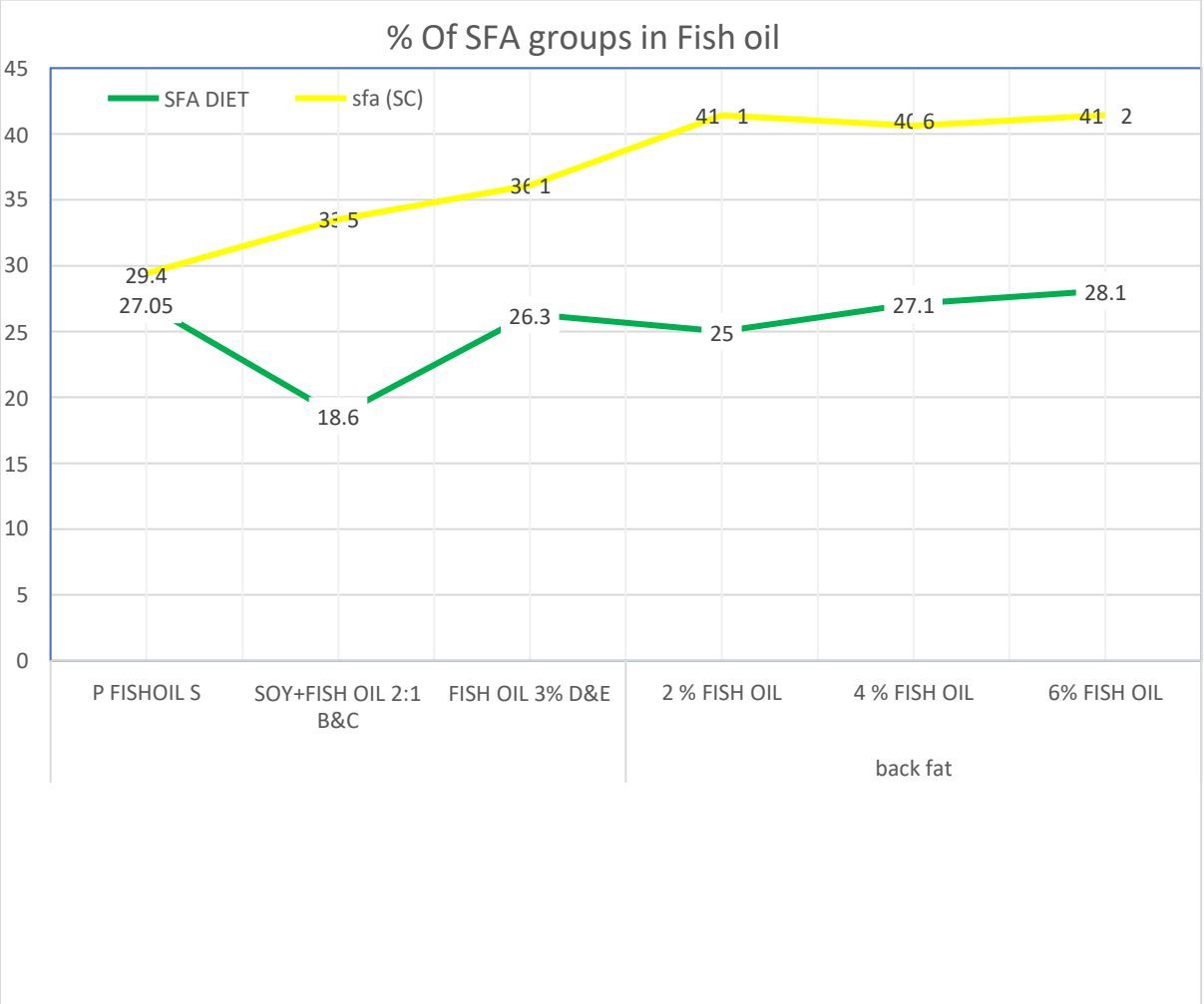

Figure 4.2.1 Summarizing the varying percentage of SFA in fat tissues compared to their diets in Fishoil fed pigs.

Summarizing Figure 4.2.1, the least SFA percentage increase between diet and SC was observed in fish oil diet (2.35 %) Morel et al., (2013) compared to all the diets studied. This might bedue to the fish oil diet being mixed up with soyabean, linseed and supplement used in that diet.

A dip in SFA percentage of diet was observed when supplemented together with soy oil at 2:1

ratio Øverland, Taugbøl, Haug, & Sundstøl, (1996). No intersection of any parameters can be noticed.

Changes in fatty acid profile

With the addition of fish oil to meals, the concentration of saturated fatty acids14:0, 16:O, and 18:O in subcutaneous fat increased ($P< 0.05$) Øverland et al., (1996).

3. Soybean oil (SBO)

Table 4.3.1 Summarizing statistical values of SFA observed in pigs fed SBO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
SFA diet	10	18.98	4.35	14.71	27.58				
SFA sc	10	31.19	3.38	25.54	36.38	22.36	0.4648	35.81	0.598
SFA lm	6	38.05	4.57	34.34	45.18	35.96	0.1081	1	0.100

sc = subcutaneous fat; lm = longissimus

SBO had third highest mean SFA percentage (Table 4.3.1) in tissues preceded only by linseed oil (Table 4.5.1) and CLA additive diets (Table 4.6.1). Greatest difference between SFA mean percentage of fat tissues SC and LM was observed in SBO (6.86 %). Soyabean oil dominated linseed oildiet in terms of greater regression intercept in both SC and LM.

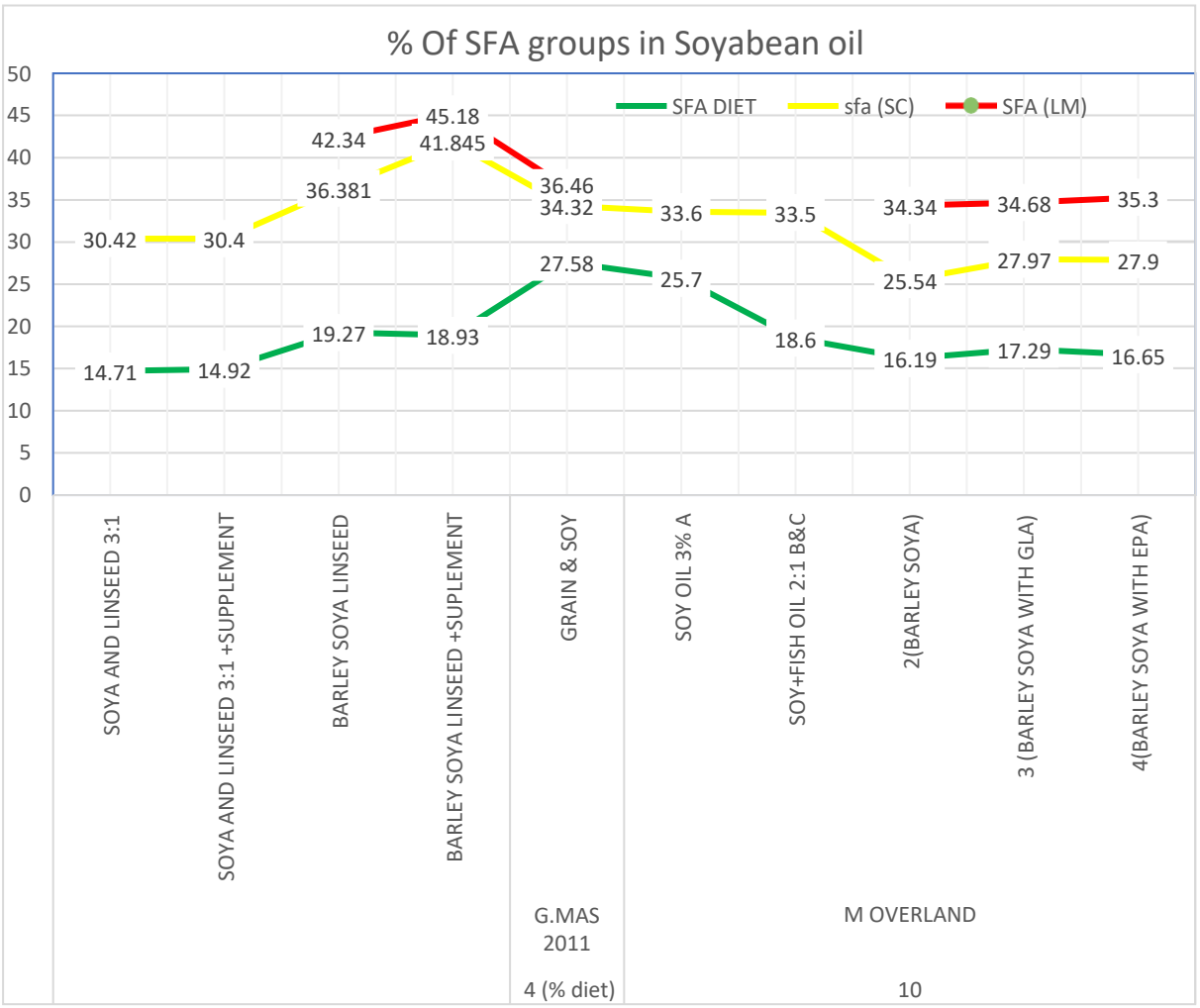

Figure 4.3.1 Summarizing the varying percentage of SFA in fat tissues compared to their diets inSoyabean meal/oil fed pigs.

Summarizing Figure 4.3.1, a consistent trend was observed between SFA percentage of SC and LM with SFA (LM) being greater than SFA (SC) when presented together.

4. Sunflower Oil (SFO)

Table 4.4.1 Summarizing statistical values of SFA observed in pigs fed SFO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
SFA diet	4	12.82	3.94	8.19	16.80				
SFA sc	3	31.92	7.62	23.57	38.50	9.916	1.640	97.68	0.988
SFA lm	3	34.96	2.30	32.32	36.51	29.83	0.4273	66.71	0.817

sc = subcutaneous fat; lm = longissimus

Least mean SFA percentage in diet was observed in sunflower oil treatments (12.82%) hence they displayed greater difference between SFA percentage of diet and tissues (19%) (Table 4.4.1). The same Table also displays the greatest correlation considering all lipid sources between diet and SC is found in sunflower oil diet (0.988), similarly the highest correlation between diet and LM was also noted in sunflower diet (0.817).

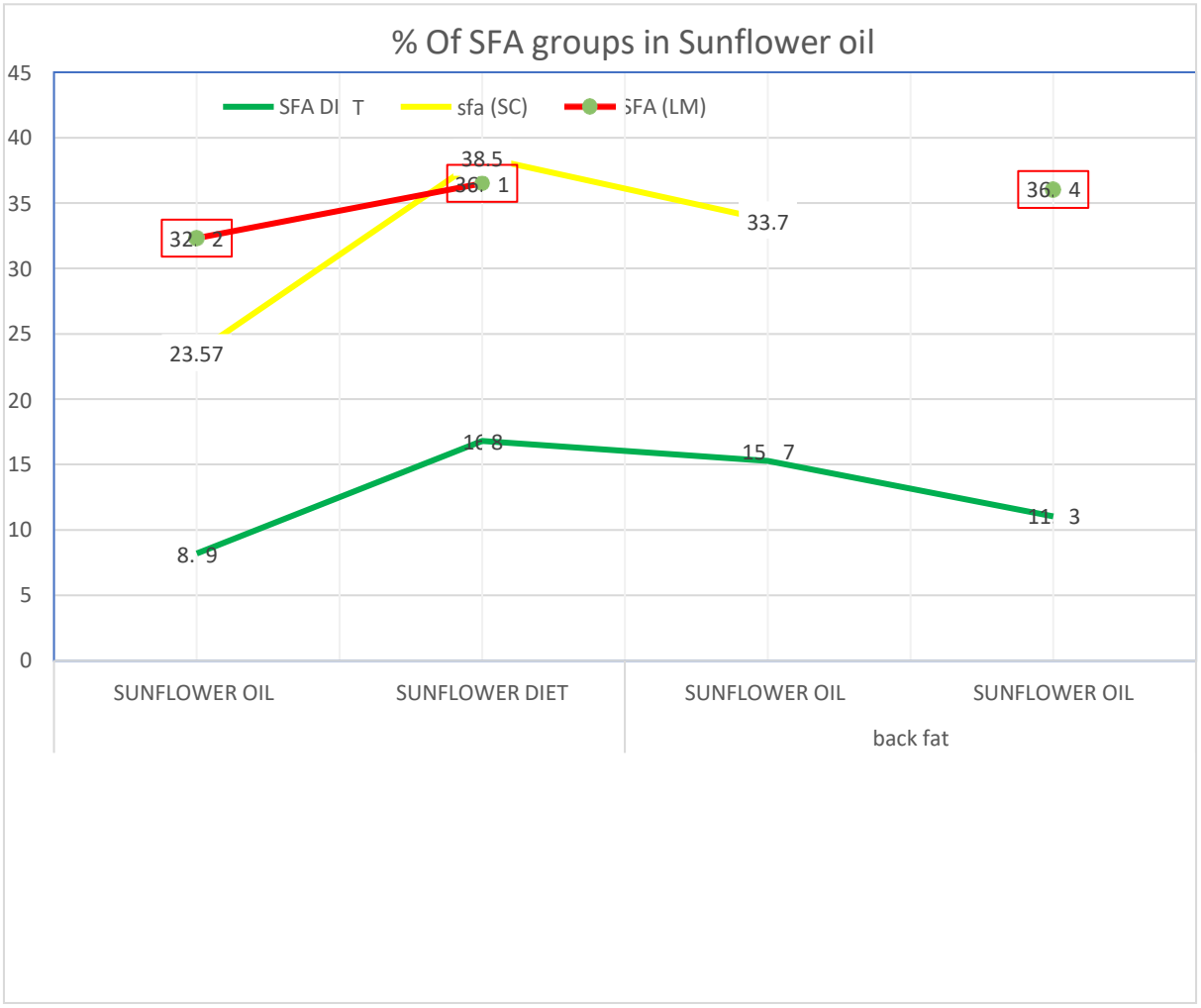

Figure 4.4.1 Summarizing the varying percentage of SFA in fat tissues compared to their diets insunflower oil fed pigs.

Summarizing Figure 4.4.1, SFA(LM) had higher SFA percentage compared to SFA(SC) though the latter dominated in 1 dietary treatment Guillevic et al., (2009).

Changes in fatty acid profile

The degree of saturation in the SFO treated longissimus muscle was lower in concentrations of SFA (15:0, 16:O) Miller et al., (1990). In the same experiment, the author also reported that in both SC and LM, the percentage of total saturated fatty acids (14:0, 15:0, 16:O, and 18:O) decreased from approximately 40% in the control to approximately 25%, 24% for the safflower oil and sunflower oil respectively Miller et al., (1990).

5. Linseed oil (LO)

Table 4.5.1 Summarizing statistical values of SFA observed in pigs fed LO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
SFA diet	7	15.76	4.49	6.78	19.80				
SFA sc	6	35.45	4.49	30.40	41.84	14.47	1.216	39.75	0.630
SFA lm	5	39.32	4.23	35.26	45.18	34.27	0.3133	16.24	0.403

sc = subcutaneous fat; lm = longissimus

Linseed diet had the highest mean percentage increase (20%) between diets and fat tissues. This might be due to its lower SFA percentage in diet (Table 4.5.1). Linseed oil diet had second highest mean SFA percentage in SC and LM (35.45 and 39.32) with the greatest being the CLA additive diet (Table 4.6.1). Next to soyabean oil diet, the greatest difference between SFA mean percentage of fat tissues was observed in linseed diet (3.87%).

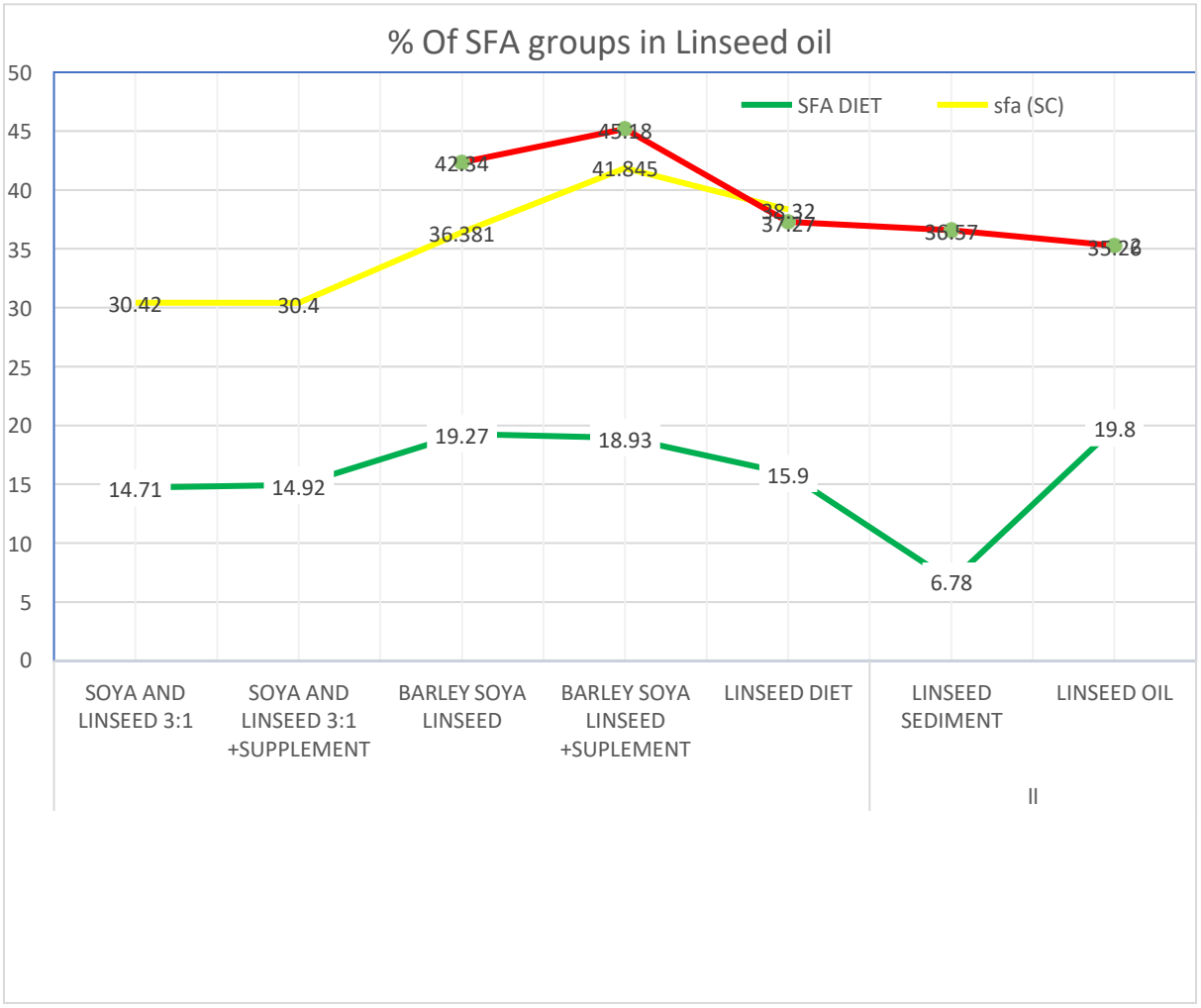

Figure 4.5.1 Summarizing the varying percentage of SFA in fat tissues compared to their diets inlinseed oil fed pigs.

Summarizing Figure 4.5.1, SFA (LM) and SFA (SC) followed similar pattern of dominance over each other's mean SFA percentage as in sunflower oil diet with SFA (SC) being the greatest once(Figure 4.4.1). Maximum increase in SFA percentage between diet and LM was observed in linseed diet (29.79) Guillevic, Kouba, & Mourot, (2009) and in SC it was (22.91) Morel et al., (2008).

Changes in fatty acid profile

The fatty acid study revealed that palmitic (C16:0) and stearic (C18:0) fatty acids predominated in the meat of both control and LO treated pigs, with no difference between the two groups Fontanillas et al., (1997). Okrouhlá, Stupka, Čítek, Šprysl, & Brzobohatý, (2013) found a similar result for stearic (C18:0) fatty acid in the flesh of pigs fed linseed, but in contrast to Fontanillas et al., (1997) findings, the same author found a much lower concentration of palmitic (C16:0) fatty acid in the meat of pigs fed linseed.

6. CLA additive diets

Table 4.6.1 Summarizing statistical values of SFA observed in pigs fed CLA added diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
SFA diet	5	23.95	5.62	14.42	28.18				
SFA sc	4	42.73	4.65	36.69	47.36	95.27	-1.996	79.62	-0.892
SFA lm	5	45.35	4.63	39.77	51.11	37.14	0.3432	17.33	0.416

sc = subcutaneous fat; lm = longissimus

CLA diets displayed similar SFA percentage (19%) difference between diet and tissues as sunflower oil (19%) (Table 4.4.1). As shown in Table 4.6.1, CLA additive diets had the highest mean SFA percentage in SC (42.73) and LM (45.35) followed by linseed oil diet (Table 4.5.1). CLA diets alsohad the highest regression intercepts compared to all other diets (Table 4.6.1).

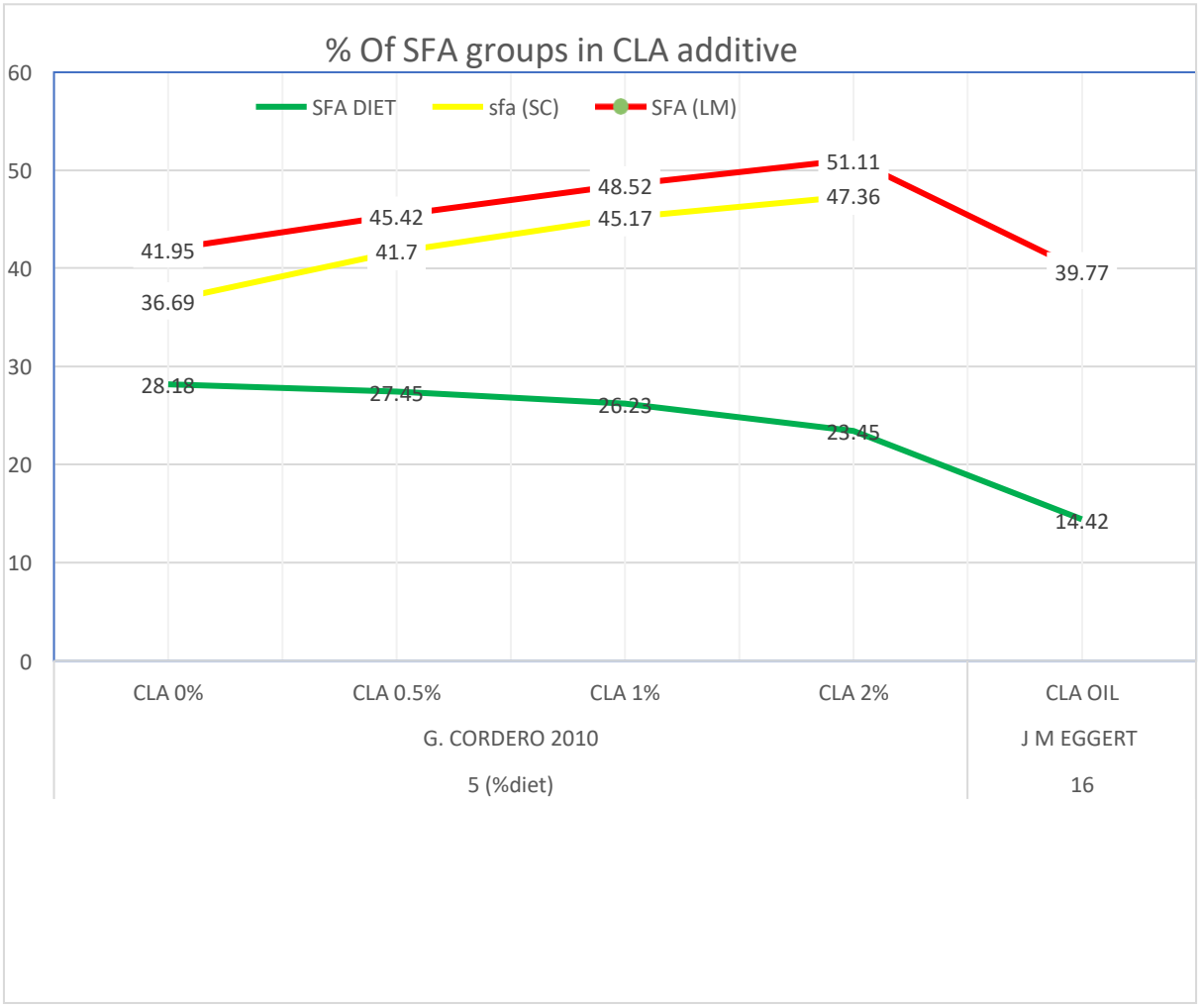

Figure 4.6.1 Summarizing the varying percentage of SFA in fat tissues compared to their diets in CLAadditive fed pigs.

Summarizing Figure 4.6.1, SFA(LM) had the greatest mean SFA percentage and followed a consistentpattern as observed in soyabean oil diet (Figure 4.3.1). Maximum increase in SFA percentage betweendiet and LM was observed in linseed diet followed by CLA additive diet (27.66) (Cordero et al., 2010) and in SC it was observed in CLA additive diets (23.91) (Cordero et al., 2010).

Changes in fatty acid profile

The CLA concentration in the feed had an increased impact on the concentrations of C12:0, C14:0, C16:0, C18:0, SFA, c9, t11-CLA, and t10, c12-CLA ($P < 0.05$) Cordero et al., (2010).

However, it's worth noting that the C16:1 n-7/C16:0 ratio has a linear response, whereas the C18:1 n-9/C18:0 ratio has a linear plus quadratic response, implying that saturation occurred at a high dietary CLA concentration Cordero et al., (2010). It's also worth noting that the increase in C16:0 concentration was higher in IMF than in subcutaneous fat, whereas the opposite was true for C18:0, revealing that CLA has a different regulatory effect in different tissues Cordero et al., (2010). However, these findings contradict those of Demaree, Gilbert, Mersmann, & Smith, (2002); Eggert, Belury, Kempa-Steczko, Mills, & Schinckel, (2001) who found an increase in C18:0 in Longissimus dorsi IMF as dietary CLA levels increased, but no significant effect on C16:0 proportions.

CLA supplemented diets had diminished oleic 18:1 and eicosenoic 20:1 and had greater proportions of SFA 14:0, 16:0 and 18:0. This reaction of suppressing MUFA concentrations by the effect of elevated SFA concentrations can be attributed to inhibitory effect of CLA on the enzyme stearoyl-CoA desaturase Lee, Pariza, & Ntambi, (1998)

While dietary CLA raises deposited CLA levels, it also changes the fatty acid composition, which does not match the dietary fat composition (i.e., CLA, a polyunsaturated fatty acid, increased saturated and decreased unsaturated fatty acids in both the longissimus muscle and the belly). A decrease in desaturase enzyme activity is most likely to blame for the change in fatty acid composition Eggert et al., (2001).

Demaree et al., (2002); Eggert et al., (2001) found an increase in C18:0 and a decrease in C18:1n-9 and C18:3 n-3 in Longissimus dorsi IMF as dietary CLA levels increased, but no significant effect on C16:0 proportion.

Longissimus muscle of CLA fed gilts contained greater total CLA (0.55 vs 0.09, $P< 0.001$), more saturated fatty acids (SFA; $P < 0.01$), and less unsaturated fatty acids (UFA: $P< 0.01$), resulting in higher SFA:UFA ratio ($P< 0.01$) compared to SFO and refined SFO diets Eggert et al., (2001).

7. Special oils (SO)

Table 4.7.1 Summarizing statistical values of SFA observed in pigs fed SO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
SFA diet	9	20.14	6.71	7.69	30.00				
SFA sc	6	34.82	6.08	24.08	41.00	19.76	0.7023	82.41	0.908
SFA lm	9	35.020	2.650	31.720	38.890	32.78	0.112	7.92	0.281

sc = subcutaneous fat; lm = longissimus

Highest correlation between diet and SC was found in SFO diet (Table 4.4.1) followed by special oil diet (0.908) (Table4.7.1).

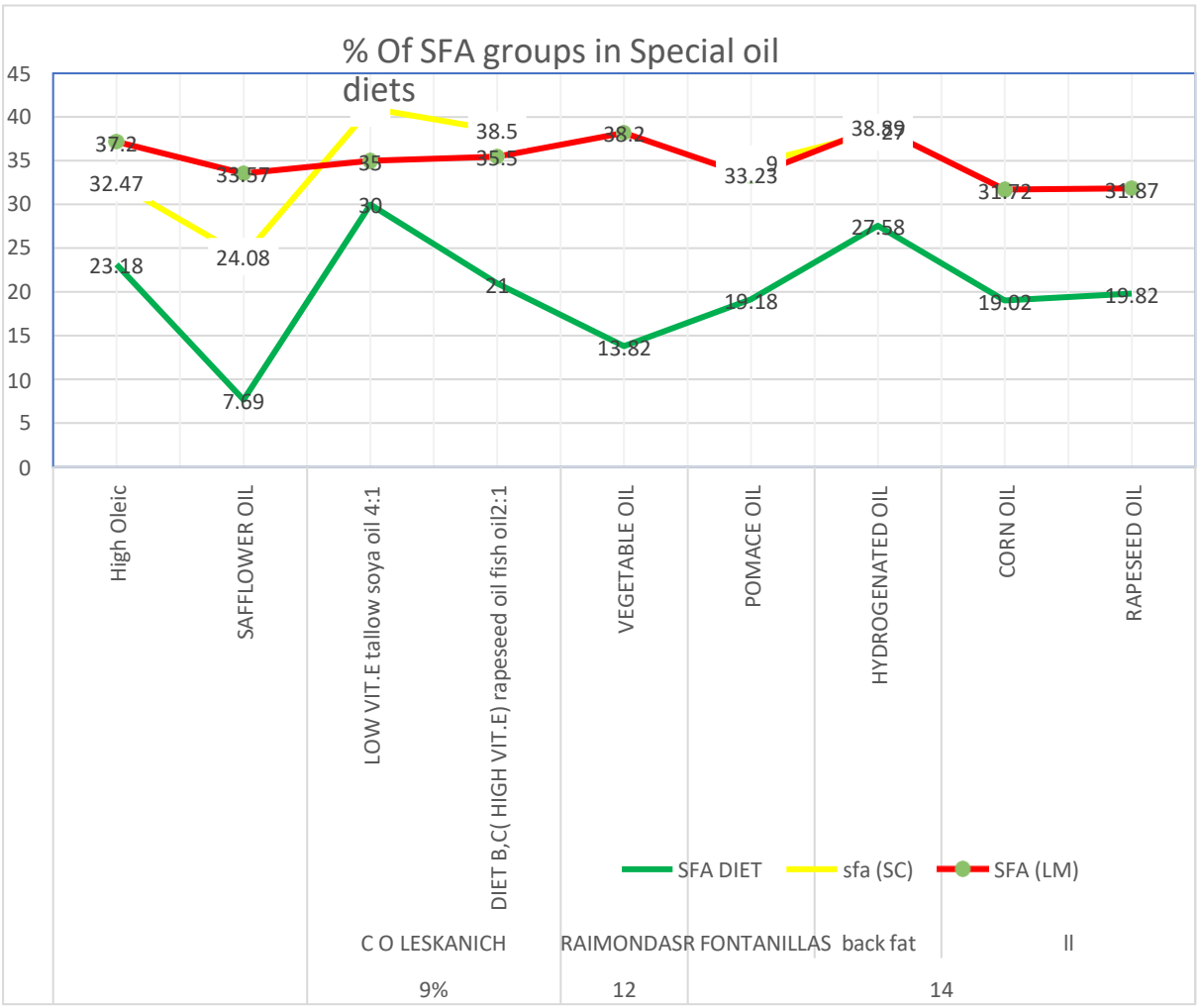

Figure 4.7.1 Summarizing the varying percentage of SFA in fat tissues compared to their diets inSpecial oil fed pigs.

Summarizing Figure 4.7.1, an inconsistent pattern of SFA(LM) and SFA(SC) is witnessed due to special oil diets group being made up of different types of vegetable oils (corn oil, rapeseed oil, hydrogenated coconut oil and pomace oil) and blends (tallow soya oil blend and rapeseed fish oil blend). Keeping aside the inverse relation observed in animal tallow diet, special oils diet displayed least SFA percentage increase between diet and LM (5%) Leskanich, Matthews, Warkup, Noble, & Hazzledine, (1997). This might be due to the inclusion of tallow as a blend with soya bean oil 4:1.

Changes in fatty acid profile

When compared to control diet, SC from pigs fed High Oleic diet had reduced (P<0.05) levels of total SFA (32.47 vs. 34.32 %), palmitic (C16:0, 20.10 vs. 21.22 %, respectively), and arachidic fatty acids (C20:0, 0.16 vs. 0.29 %, respectively) Mas et al., (2011).

Christensen, (1963) substituted either coconut fat or soy oil for 30 % of the dietary energy in a control diet. He observed that the coconut fat was only retained in small amounts of C12:0 and C14:O in the back fat.

Monosaturated Fatty acids

1. Animal Fat / Tallow (AT)

Table 4.1.2 Summarizing statistical values of MUFA observed in pigs fed AT diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
Mufa diet	7	35.11	7.84	27.61	48.70				
mufa sc	6	47.32	4.43	39.95	53.20	34.69	0.3474	37.3	0.611
mufa lm	5	45.79	4.75	40.49	52.05	44.60	0.0338	0.37	0.061

Sc = subcutaneous fat; lm = longissimus

Animal tallow (Table 4.1.2) and special oil diets (Table 4.7.2) displayed higher MUFA SC percentage compared to LM whereas all other diets contradicted this with higher MUFA percentage beingobserved in muscles but not fat tissue (Tables in this section ending with 2).

AT diets displayed greatest increase in regression intercept of SC (34%) highlighting its efficiency in incorporation of MUFA into adipose tissues.

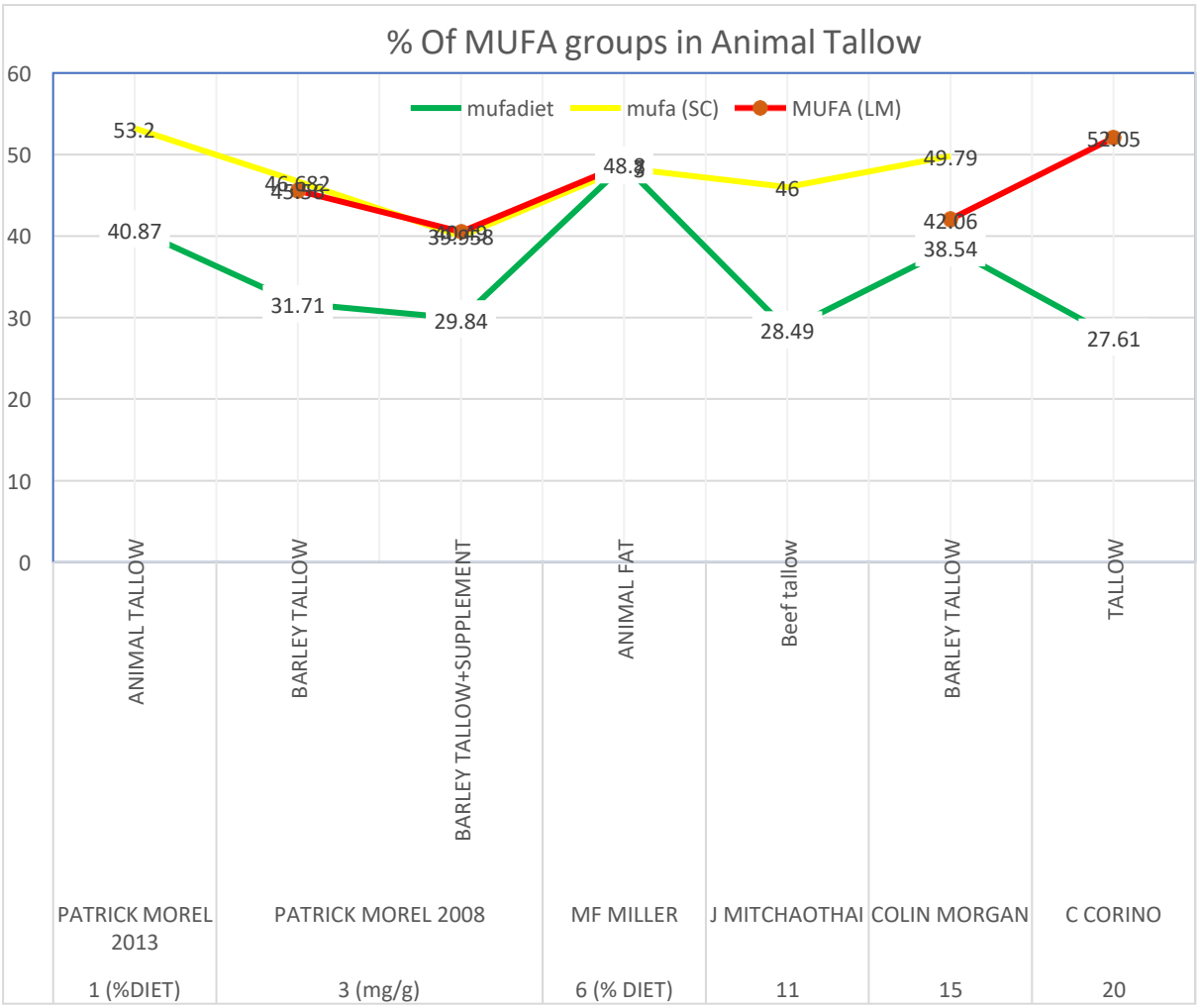

Figure 4.1.2 Summarizing the varying percentage of MUFA in fat tissues compared to their diets inanimal tallow fed pigs.

Summarizing Figure 4.1.2, we can notice MUFA percentage in diet being lower or equal to its percentage in tissues which is different compared to SFA, where diet always had greater SFA percentage than tissue mean percentage indicating SFA dominance in animal tallow diets. MUFA(SC) and MUFA(LM) were similar when presented together except in the study of Morgan et al., (1992) with SC dominating LM. Miller et al., (1990) experimented with high percentage MUFA diet resulting in least difference observed between diet and

tissues.

Changes in fatty acid profile

The effect of dietary fat of AT was visible here as well. AT had higher amounts of palmitoleic acid in the LM than all 3 CLA- added diets. Palmitoleic acid is also produced by the metabolism of palmitic acid Gurr & James, (1980) which was greatest with AT Morgan et al., (1992). He also found that, AT increased the levels of oleic acid in the semitendinosus, as well as the outer and inner backfat, despite the fact that it did not contain significantly more oleic acid than the other diets Morgan et al., (1992).

The levels of monounsaturated fatty acids (MUFA) were greater ($P<0.001$) in all tissues of pigs fed AT Mitchaothai et al., (2007).

2. Fish Oil (FO)

Table 4.2.2 Summarizing statistical values of MUFA observed in pigs fed FO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
MUFA diet	6	22.33	3.21	18.10	24.70				
MUFA sc	6	39.662	2.225	36.100	42.770	27.88	0.5274	57.99	0.762

sc = subcutaneous fat.

Greatest mean percentage increase between diets and SC was found in fish oil diet (17%). This may be as MUFA mean diet percentage is least (22.3) (Table 4.2.2) in fish oil diets which is greatest compared to other diets resulting in the above-mentioned increase.

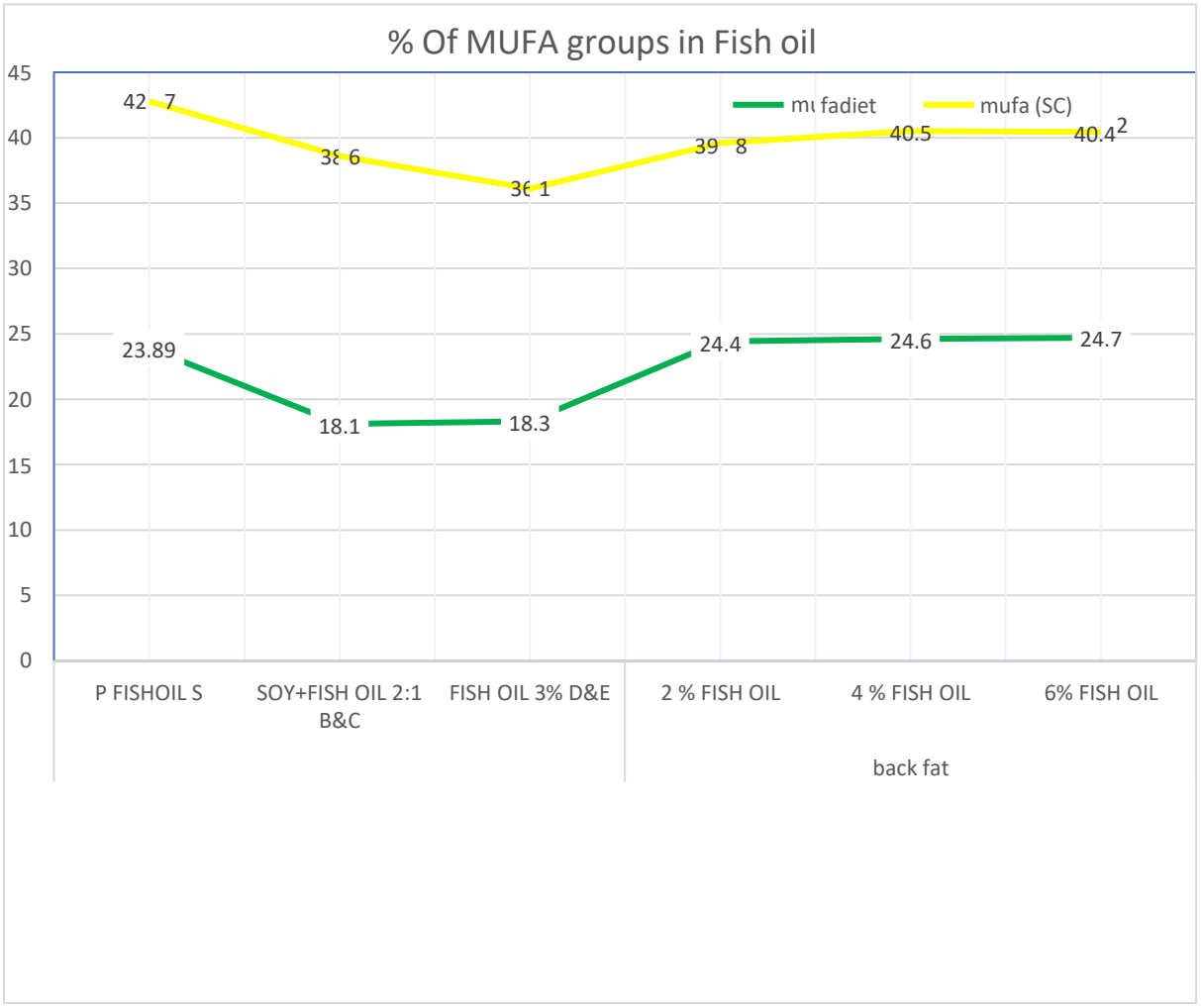

Figure 4.2.2 Summarizing the varying percentage of MUFA in fat tissues compared to their diets inFish oil fed pigs.

Summarizing Figure 4.2.2, by observing last 3 values reported by Irie & Sakimoto, (1992), the increase in percentage of fish oil supplied in the diet did not cause any differences in overall MUFA(SC) and seemed to be in constant with other fish oil diets with lesser percentage.

Changes in fatty acid profile

Supplementing with fish oil increased ($P < 0.05$) the concentrations of the fatty acids 16:1 andC18:1n-9 in subcutaneous fat Øverland et al., (1996) but decreased ($P < 0.05$) the concentrations of the fatty acids 18:2n-6 and 20:4n-6 (PUFA).

3. Soya Bean Oil (SBO)

Table 4.3.2 Summarizing statistical values of MUFA observed in pigs fed SBO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
MUFA									
Diet	10	25.30	12.83	1.20	42.58				
MUFA sc	10	39.03	5.84	29.53	48.30	30.78	0.3260	51.27	0.716
MUFA lm	6	40.28	6.25	34.71	49.65	60.91	-0.8329	89.33	-0.945

sc = subcutaneous fat; lm = longissimus

A stronger negative correlation is observed between diet and LM (-0.945) (Table 4.3.2) indicating that an increase in MUFA diet might result in a decrease in MUFA LM in SBO fedpigs.

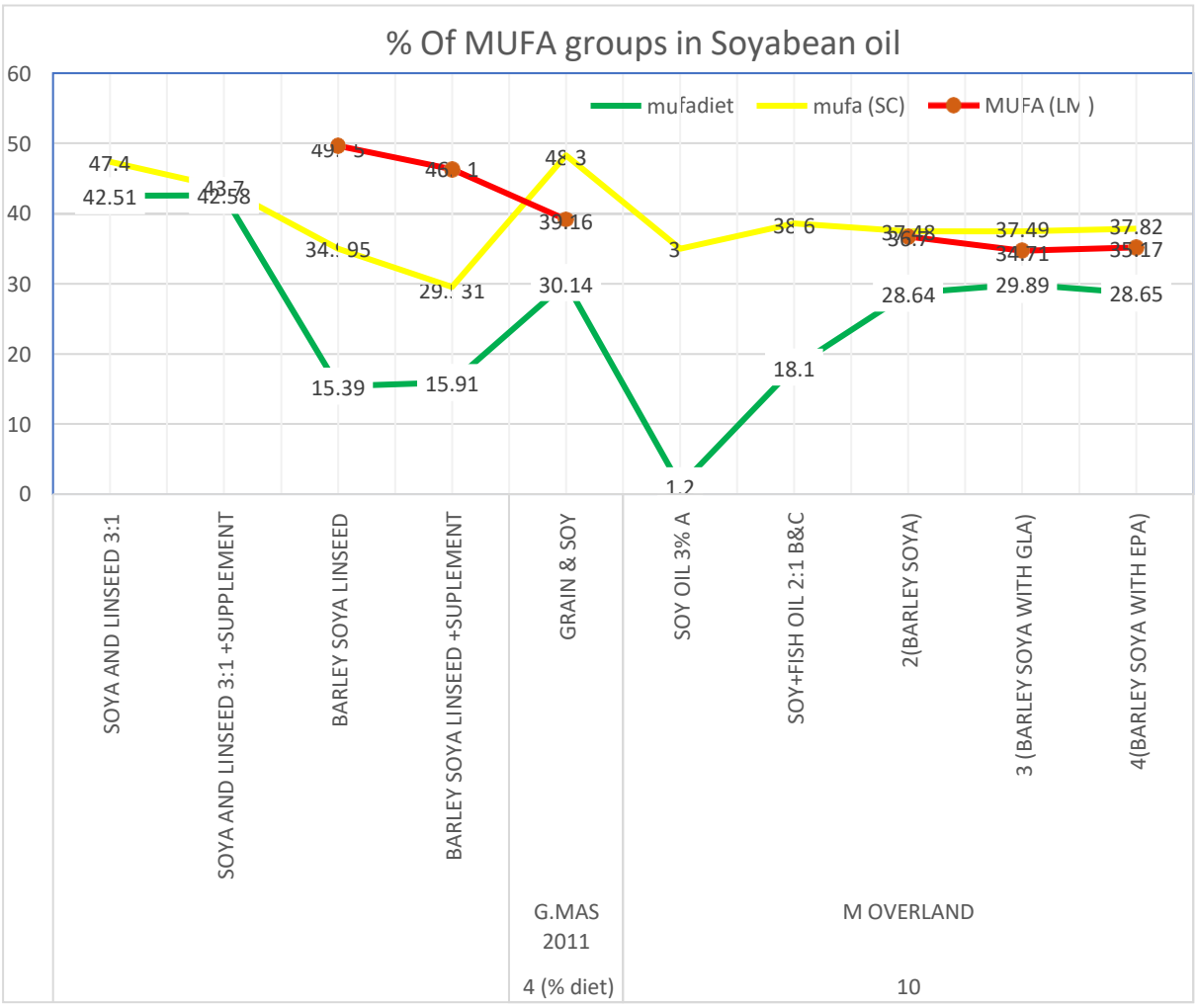

Figure 4.3.2 Summarizing the varying percentage of MUFA in fat tissues compared to their diets inSoyabean meal/oil fed pigs.

Summarizing Figure 4.3.2, a constant pattern was not found among our 3 parameters. This may be due to soyabean being mixed with other ingredients like linseed, fish oil and supplements which brought out the noticeable differential changes as compared to using an unadulterated soy oil of 3% brought out the most noticeable decrease in the MUFA diet percentage to 1.2 which is the least among all the dietary treatments studied. This decrease did not cause any fluctuation to MUFA(SC) which remained constant with other soyabean diets resulting in the greatest MUFA percentage difference between diet and SC (38.8%) indicating extreme *de-novo* synthesis of MUFA from SFA.

4. Sunflower Oil (SFO)

Table 4.4.2 Summarizing statistical values of MUFA observed in pigs fed SFO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
MUFA diet	4	39.3	28.4	19.1	80.9				
MUFA sc	3	48.19	12.22	40.95	62.30	30.11	0.3928	96.81	0.984
MUFA lm	3	51.15	5.81	44.58	55.60	46.89	0.1034	37.61	0.613

sc = subcutaneous fat; lm = longissimus

Highest MUFA mean percentage in tissues SC (48%) and LM (51%) was observed with SFO treatments (Table 4.4.2) followed by SO (Table 4.7.2). Both oils also displayed highest mean percentage of MUFA in diets (39.3 and 40.6 %) respectively. These results were anticipated since the addition of sunflower and safflower oils to the diet increased the amount of oleic acid deposited in swine adipose tissues without affecting carcass quality Miller et al., (1990). One of the greatest increases in regression intercept is observed in sunflower oil diet for SC (30.1%) and in LM sunflower oil had highest increase (46.89%) compared to all other diets.

Like SFA, highest correlation between MUFA diet and SC is found in sunflower diet (0.984) followed by special oils diet (0.949). Similarly, greatest correlation between diet and LM is observed in the same diets SFO (0.613), SO (0.370) respectively.

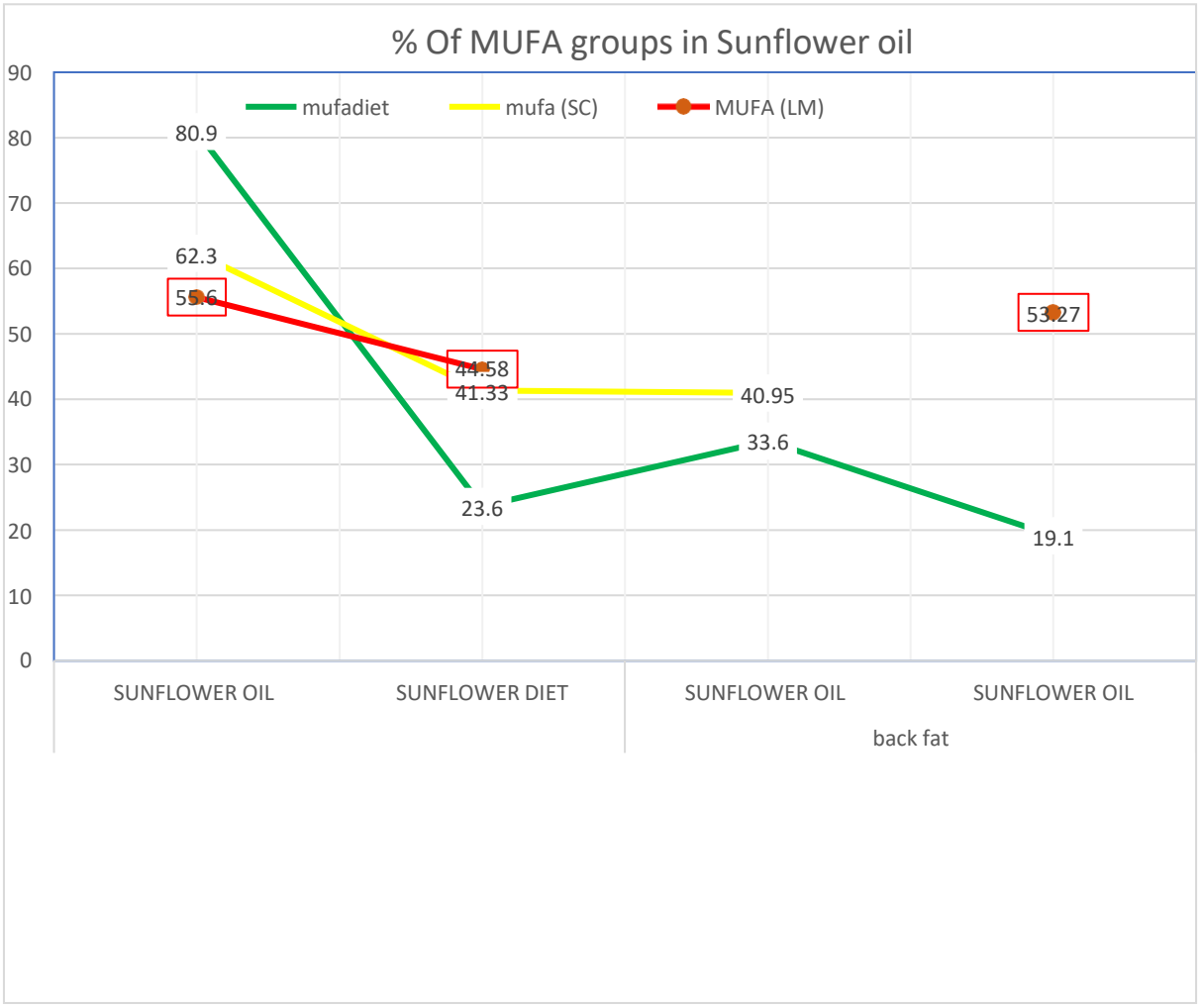

Figure 4.4.2 Summarizing the varying percentage of MUFA in fat tissues compared to their diets insunflower oil fed pigs.

Summarizing Figure 4.4.2, the highest MUFA percentage in diet was observed in sunflower oil diet (80.9%) Miller et al., (1990). These oils had a low enough degree of poly unsaturation to produce carcasses that could be processed in the meat industry Miller et al., (1990). Pork chops from pigs fed sunflower or safflower oil had higher levels of oleic fatty acids than porkchops from control pigs Guillevic et al., (2009). Diet effect seems inconsistent because a similar MUFA(LM) was observed for different MUFA diet percentage (80.9 and 19.1) indicating additional factors playing a role in incorporation of MUFA into tissues other than diet.

Changes in fatty acid profile

Discussing subcutaneous fat and intramuscular tissue concurrently, between the control and sunflower oil treatments, the percentage of 18: 1 increased by about 17%, and the ratio of monounsaturated fat (16: l and 18: 1) to saturated fat increased from 1.2 to 1.6, 2.4, 2.6, and 2.2 for the animal fat, safflower oil, sunflower oil, and canola oil treatments, respectively Miller et al., (1990). When compared to the control, the addition of animal fat (40.5 % of total), safflower oil (51.4 %), sunflower oil (57.3 %), and canola oil (45.6 %) enhanced the amounts of oleic acid (37.7 %) Miller et al., (1990). These resultsclearly suggest that SFO diet brings out the maximum changes related to MUFA in pigs. Miller et al., (1990) found highest percentages of oleic acid (54.80%) in animals fed 10% safflower oil (72.1 % oleic acid in the diet).

Intramuscular fat had a weaker response to dietary treatment of fatty acid composition than subcutaneous fat, according to Fontanillas et al., (1997) and Miller et al., (1990). The degree of saturation in the sunflower oil treated longissimus muscle was lower in concentrations of SFA (15:0, 16:O) Miller et al., (1990). We already know that these fatty acids are cholesterol contributors and a decrease in their percentage is desired. As a result, the reduction of this saturated fatty acid may be just as important as the increase in oleic acid in lowering cholesterol levelsin human serum and lowering the risk of coronary heart disease Miller et al., (1990).

Additional to SFO, HOP (High Oleic Peanuts) was higher in monounsaturated fatty acids, primarily C18: 1, and lower in polyunsaturated fatty acids, primarily C18:2 control pigs, when compared to RP (Regular Peanuts). Each of the three-dietary fat/oil sources increased total monounsaturated fatty acids in the carcass fat (P.01) when compared to the control; HOP resulted in the greatest increase (32% increase) Miller et al., (1990).

In terms of total polyunsaturated fatty acids, the RP and CO fat/oil sources both increased (whereas the HOP fat/oil source decreased ($P < .05$) when compared to the control pigs.

HOP had similar total monounsaturated fatty acids to other high-oleic vegetable oils like high-oleic sunflower and safflower oils but had lower total polyunsaturated fatty acids (40/0 vs 10 to 15% Miller et al., (1990); Rhee, Davidson, Cross, & Ziprin, (1990).

5. Linseed Oil (LO)

Table 4.5.2 Summarizing statistical values of MUFA observed in pigs fed LO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
MUFA									
Diet	7	27.71	11.54	15.39	42.58				
MUFA sc	6	39.07	6.44	29.53	47.40	27.16	0.4399	72.82	0.853
MUFA lm	5	45.87	3.82	40.89	49.65	46.66	-0.0362	0.41	-0.064

sc = subcutaneous fat; lm = longissimus

Next to fish oil, highest mean percentage increase between diets and tissues was found in linseed oildiet (18%) which can be attributed to its lower mean percentage MUFA in diet (27.71) compared to all other diets. A slight negative correlation is found in between MUFA diet and MUFA LM (-0.064).

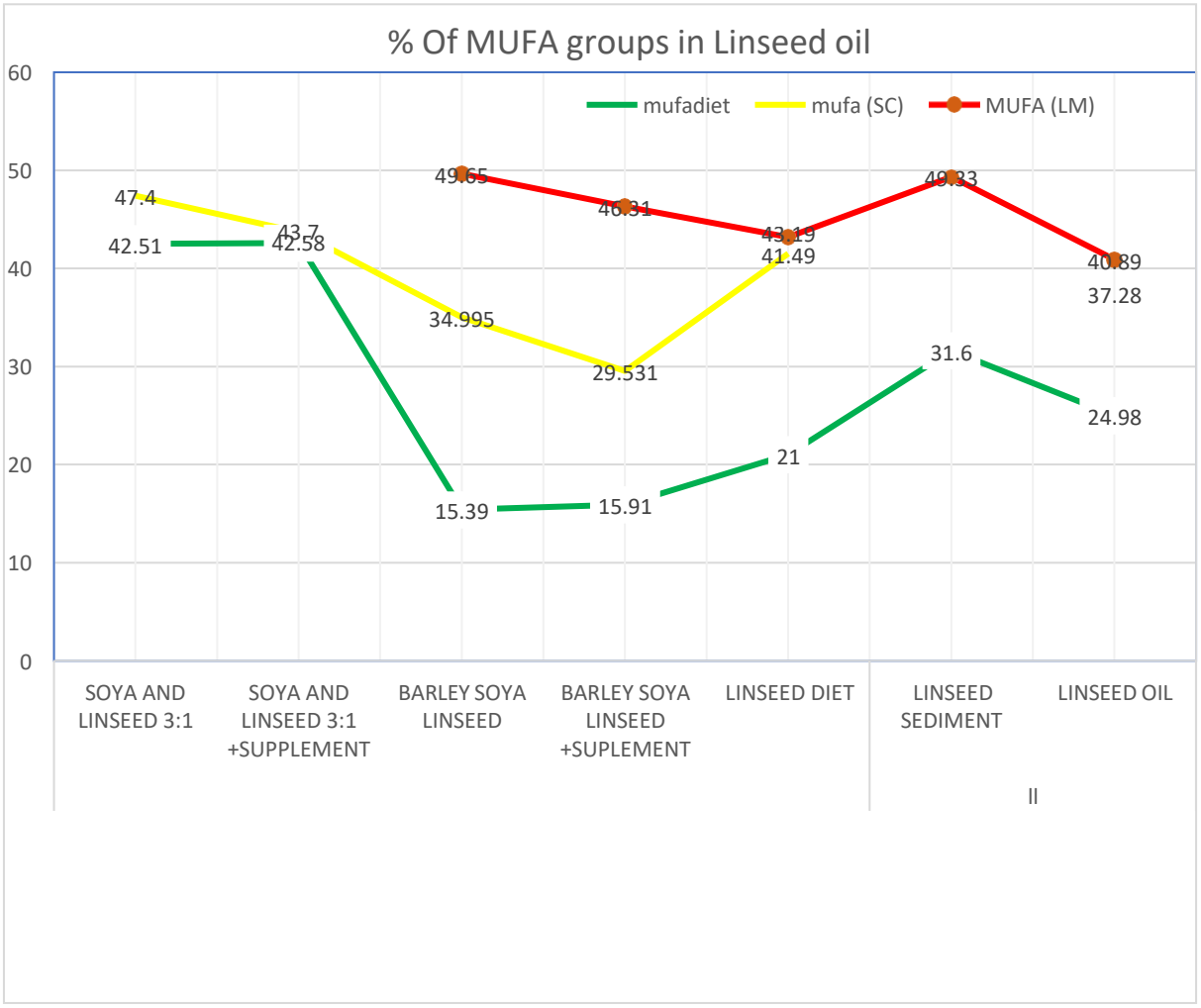

Figure 4.5.2 Summarizing the varying percentage of MUFA in fat tissues compared to their diets inlinseed oil fed pigs.

Summarizing Figure 4.5.2, MUFA(LM) dominated over MUFA(SC) when presented together.

Changes in fatty acid profile

Linseed in the diet of pigs reduces total MUFA, according to Bečková & Václavková, (2010) and Okrouhlá et al., (2013). In contrast to this Leikus et al., (2018) did not find this effect.

The linseed oil treatment resulted in significantly decreased levels of palmitoleic (C16:1n-7) and vaccenic (C18:1n-7) Leikus et al., (2018). In the study with linseed, Okrouhlá et al., (2013) also found a decreased concentration of palmitoleic (C16:1n-7) fatty acid, but because MUFA can be produced in the pig body, their contents in meat are not as essential as PUFA Enser, Richardson, Wood, Gill, & Sheard, (2000); Gordana Kralik, Margeta, Suchý, & Straková, (2010).

Leikus et al., (2018) reported a decreased MUFA:PUFA ratio, consistent with the findings of Okrouhlá et al., (2013), who also found that dietary linseed supplementation reduced the MUFA:PUFA ratio. The meat of pigs fed a linseed sediment diet showed a tendency towards a higher content of erucic (C22:1n-9) fatty acid (+0.01 %; P< 0.10) Leikus et al., (2018).

6. CLA additive diets

Table 4.6.2 Summarizing statistical values of MUFA observed in pigs fed CLA- added diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
MUFA diet	5	28.11	3.10	22.60	29.84				
MUFA sc	4	41.16	5.95	34.84	48.79	404.3	-12.32	70.73	-0.841
MUFA lm	5	42.13	6.15	35.93	51.62	92.64	-1.797	81.86	-0.905

sc = subcutaneous fat; lm = longissimus

Negative trend in correlation is observed in SC for CLA-added diet alone, and in LM, CLA, soyabean oil and linseed oil displayed this negative correlation trend indicating that in these diets with an increase in the MUFA percentage of diet there is a decrease in MUFA percentage of tissues especially in LM. MUFA diet remained constant with increasing CLA percentage in diets indicating its ineffectiveness in increasing MUFA percentage in tissues.

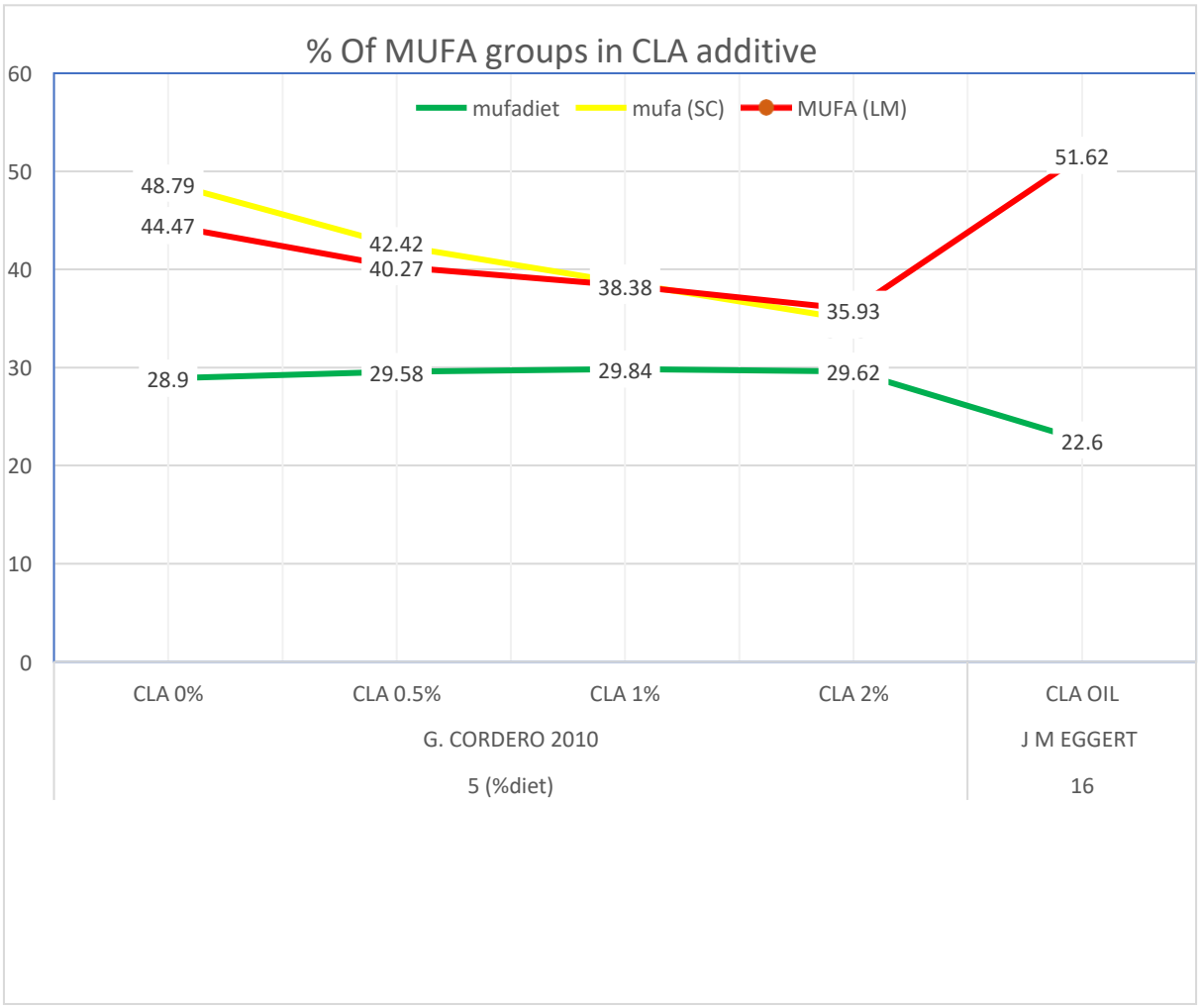

Figure 4.6.2 Summarizing the varying percentage of MUFA in fat tissues compared to their diets in CLA additive fed pigs.

Summarizing Figure 4.6.2, an inconsistent trend can be seen where MUFA SC dominated or was equal to MUFA LM, but we can notice a huge spike in MUFA LM (51.6%) almost 16% compared to previous CLA added diets which is unusual. It was almost equal to the highest MUFA LM observed in (Figure 4.4.2) SFO. This spike may be caused due to the CLA supplement used in the study by Eggert et al., (2001) had more oleic acid (22.4%) than SFO oil (18.7 %) used in the study.

Changes in fatty acid profile

Previous studies have found that dietary CLA causes an increase in C14:0, C16:0, C18:0, SFA, and a decrease in C18:1 n-9 and MUFA fatty acids in subcutaneous backfat Averette Gatlin, See, Hansen, Sutton, & Odle, (2002). The proportions of C16:1 n-7, C18:1 n-9, C18:1 n-7, and MUFA in back fat and longissimus decreased as the CLA concentration in the diet increased Cordero et al., (2010). Others have found that increasing C18:1n-9c causes a rise in mono unsaturation in animal tissues St. John et al., (1987), Miller et al., (1990) or components rich in oleic acid Myer et al., (1992).

Contradicting the above statements, Eggert et al., (2001) found that CLA- added group's longissimus muscle did not contain lower quantities of monounsaturated fatty acids (MUFA) or polyunsaturated fatty acids (PUFA) than the SFO or refined SFO groups ($P > 0.05$). In fact, he found almost equal percentage of MUFA in LM fed CLA added diet (51.62) compared to SFO (53.27), which explains the unusually higher MUFA percentage found in Figure 4.6.2 compared to other CLA- added diets.

He went on to while dietary CLA raises deposited CLA levels, it also changes the fatty acid composition, which does not match the dietary fat composition (i.e., CLA, a polyunsaturated fatty acid, increased saturated and decreased unsaturated fatty acids in both the longissimus muscle and the belly). A decrease in desaturase enzyme activity is most likely to blame for the change in fatty acid composition Eggert et al., (2001).

7. Special Oils (SO)

Table 4.7.2 Summarizing statistical values of MUFA observed in pigs fed SO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
MUFA diet	9	40.61	15.38	24.46	72.10				
MUFA sc	6	47.95	6.41	41.24	56.90	31.41	0.3626	90.14	0.949
MUFA lm	9	46.60	5.66	37.00	52.40	41.07	0.1362	13.67	0.370

sc = subcutaneous fat; lm = longissimus

Special oil diets (Table 4.7.2) and AT diet (Table 4.1.2) displayed higher MUFA SC percentage compared to LM whereas all other diets contradicted this with higher MUFA percentage beingobserved in muscles but not fat tissue.

Highest MUFA mean percentage in tissues SC (48%) and LM (51%) was observed with SFO (Table 4.4.2) treatments followed by special oil. Both oils also displayed highest mean percentage of MUFAin diets (39.3 and 40.6 %) respectively.

Like SFA, the highest correlation between MUFA diet and SC is found in sunflower diet (0.984) followed by special oils diet (0.949). Similarly, greatest correlation between diet and LM was also observed in the same diets (0.613) and (0.370) respectively.

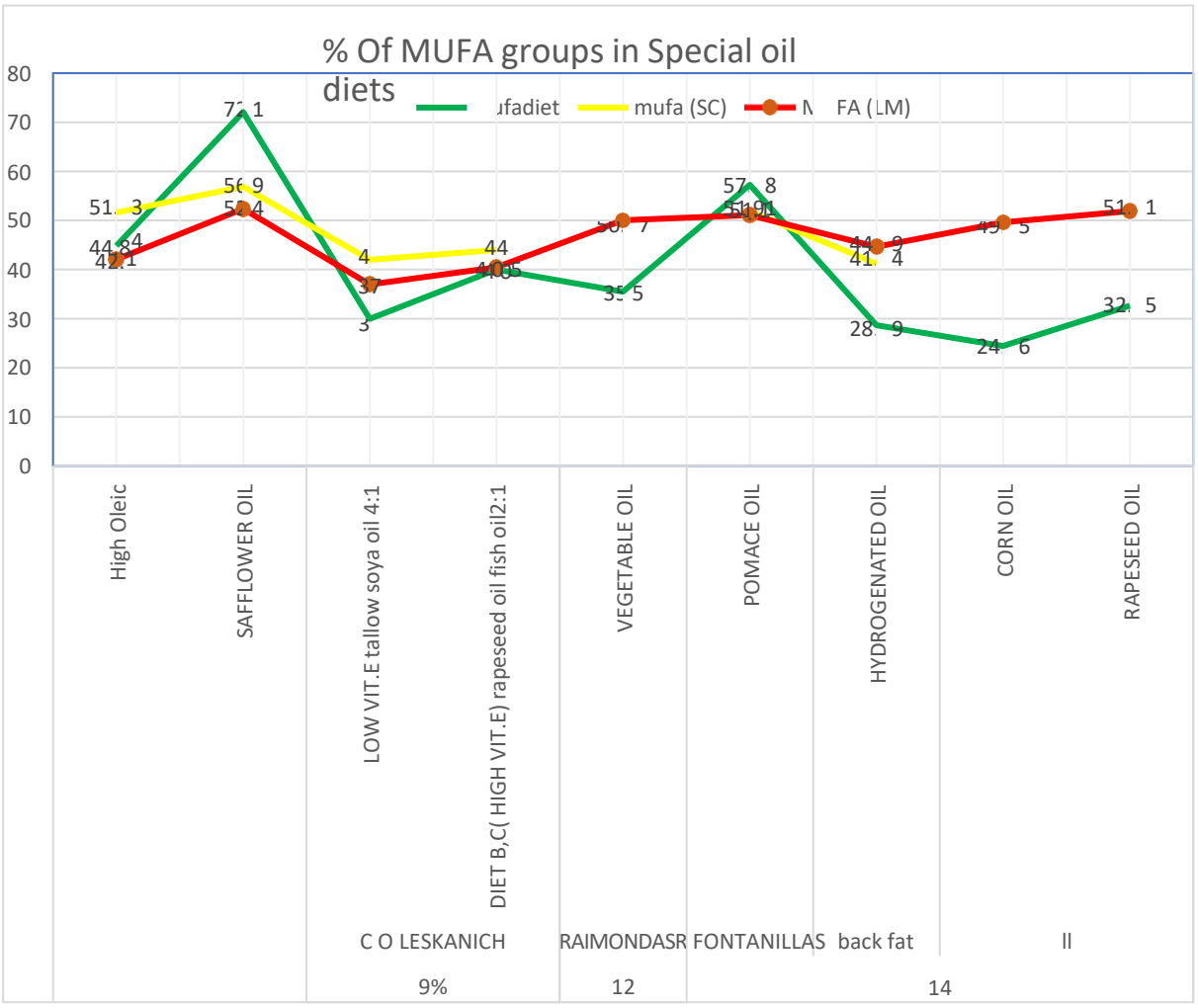

Figure 4.7.2 Summarizing the varying percentage of MUFA in fat tissues compared to their diets in Special oil fed pigs.

Summarizing Figure 4.7.2, an inconsistent pattern can be noted for all three parameters since this group is made up of different oils.

Changes in fatty acid profile

Fontanillas et al., (1997) who used pomace oil, hydrogenated fat, and linseed oil as fat sources, observed an exponential asymptotic response in BF fatty acid content due to manipulation of PUFA and MUFA contents of diets fed to pigs.

The presence of rapeseed oil increased the levels of eicosenoic (C 20:1-CIS-11) and erucic acids (both $P < .001$) Leskanich et al., (1997).

The contents of palmitoleic (C16:1n-7) and vaccenic (C18:1n-7) MUFA in the muscle of vegetable oil fed pigs were 0.61 ($P< 0.025$) and 0.57 % ($P< 0.05$) lower, respectively Leikus et al., (2018). Studies that used higher levels of oleic acid in the diet (43 % of C18:1) Mas et al., (2011) found that pigs fed MUFA-rich diets had larger proportions of total MUFA and C18:1 in intramuscular fat than control animals. Myer et al., (1992) and Fontanillas et al., (1997) fed diets with 57 % and 60 % C18:1, respectively. Miller et al., (1990) used a MUFA source (SFO) with C18:1 value ranging from 45 to 81 % which we discussed earlier. Myer et al., (1992) found a 37 % increase in C18:1 and a 31 % increase in MUFA, whereas Fontanillas, Barroeta, Baucells, & Guardiola, (1998) found a 34 % increase in C18:1 and a 29 % increase in MUFA.

The percentage of MUFA in the backfat ($P < 0.001$) was 25% higher in animals fed pomace oil than in animals fed hydrogenated coconut oil and 39% higher in animals fed linseed oil Fontanillas et al., (1997), because pomace oil had higher MUFA in diet.

In comparison to CONTROL diet fed pigs, feeding the HO diet enhanced the amount of C18:1 n-9 and MUFA in Semimembranosus subcutaneous fat (44.78 vs. 41.58 % and 51.63 vs. 48.30 %, respectively) Mas et al., (2011). Although all MUFA and oleic acid (C18:1) were numerically greater in fat from pigs fed HO compared to CONTROL (42.1 vs. 39.2 and 34.5 vs. 31.6, % respectively), there was no significant increase in overall MUFA or oleic acid in intramuscular fat from pigs fed HO Mas et al., (2011).

Mas et al., (2011) findings suggest that various tissues may respond differently to dietary changes, as feeding the HO diet increased C18:1 and MUFA percentage in subcutaneous fat without causing a significant increase in intramuscular fat.

Other parameters, like slaughter weight, carcass fatness, and animal genetics, may alter fat tissue responsiveness to MUFA enriched diets in addition to C18:1 amount in the diet and feeding times Mas et al., (2011).

Canola oil had a higher concentration of monounsaturated fatty acids than HOP Miller et al., (1990).

CO, unlike HOP, had a significant amount of polyunsaturated fatty acids, particularly the C18:3 fatty acid. When any of the three fat/oil sources was fed, total saturated fatty acids decreased; CO caused the greatest decrease Myer et al., (1992).

In both subcutaneous and intermuscular adipose tissue, the percentage of total saturated fatty acids (14:0, 15:0, 16:O, and 18:O) decreased from approximately 40% in the control to approximately 24% for canola oil treatment Miller et al., (1990).

The level of oleic acid in the longissimus muscle was not increased by feeding canola oil. These findings differ from those reported by St. John et al., (1987) Perhaps it was the high level of polyunsaturated fatty acids in our canola oil that caused this Miller et al., (1990).

Poly Unsaturated Fatty Acids (PUFA)

1. Animal Fat / Tallow (AT)

Table 4.1.3 Summarizing statistical values of PUFA observed in pigs fed AT diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
PUFA diet	7	21.20	5.68	13.65	32.11				
PUFA sc	6	14.68	2.89	11.77	19.9	14.56	0.0062	0.01	0.007
PUFA lm	5	16.57	4.32	13.10	23.92	18.95	-0.1023	1.55	-0.124

sc = sub cutaneous fat; lm = longissimus

Least mean PUFA diet (21.2 %) is obtained in AT diets (Table 4.1.3). This is expected since we know AT is primarily an SFA and MUFA source. This is also evident by looking at the least increases in regression intercept between diet and tissues. The Table above also displays that the least positive correlation between diet and PUFA SC was seen in AT diet.

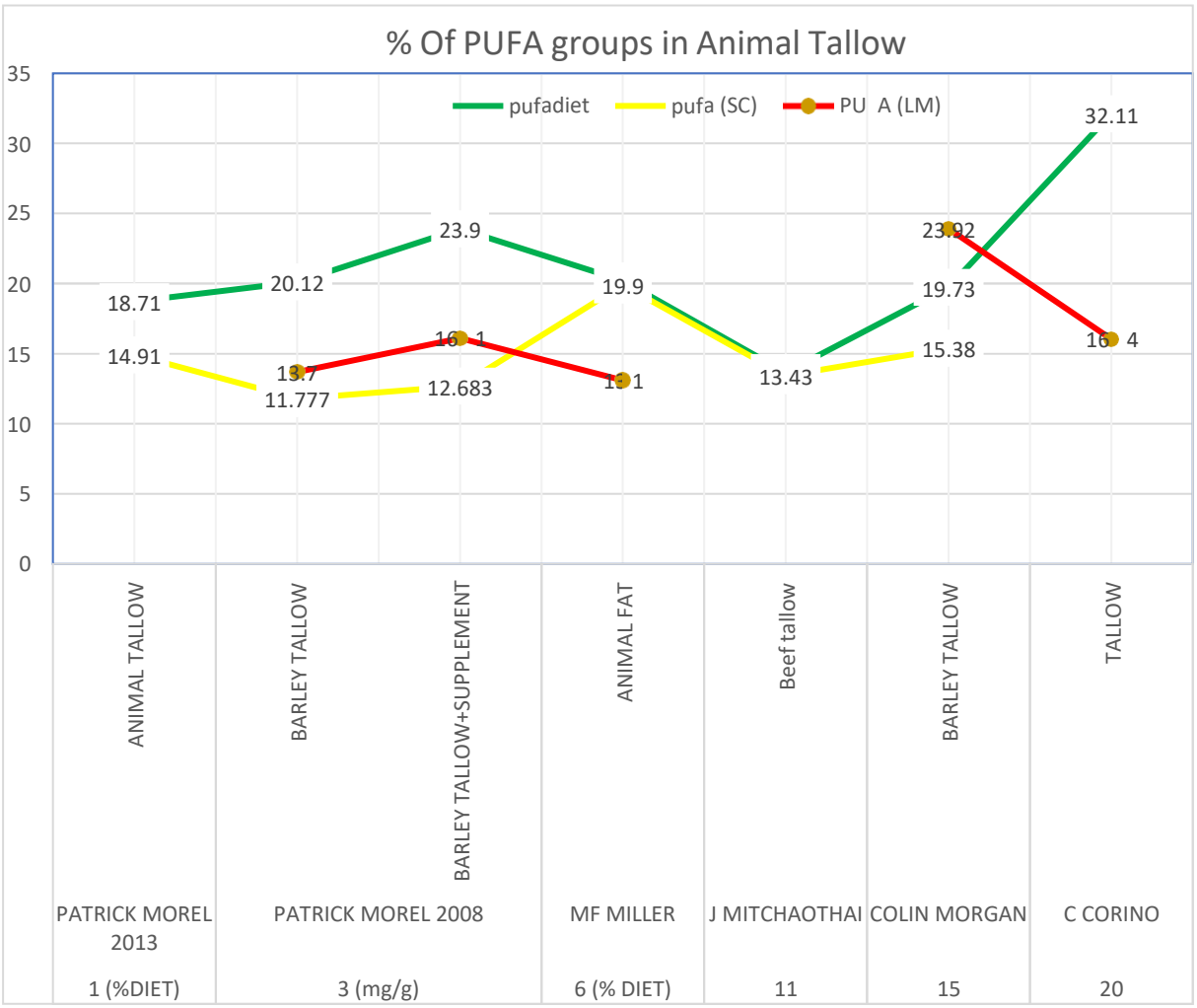

Figure 4.1.3 Summarizing the varying percentage of PUFA in fat tissues compared to their diets in animal tallow fed pigs.

Summarizing Figure 4.1.3, higher PUFA LM than diet was reported only in one dietMorgan et al., (1992). An inconsistent pattern of the three parameters can be noted. However, the levels of α-linolenic acid in the diet and adipose tissue may not be highly associated, particularly when the level in the diet is low, as in study by Mitchaothai et al., (2007). In the body, vital α-linolenic acid can become desaturated and elongated. Morecrucially, it may be preferentially oxidized for energy generation, resulting in reduced adipose tissue incorporation, as previously suggested by Leyton, Drury, & Crawford, (1987).

Changes in fatty acid profile

The amount of polyunsaturated fat in the animal fat treatments varied from control diet (13.6 % to 20.8 %) Miller et al., (1990).

Morgan et al., (1992) reported diets rich in linoleic acid, such as those including SBO resulted in significantly greater ($P < 0.001$) concentrations of this fatty acid in the semitendinosus samples than the tallow-supplemented diet. Although the L dorsi levels in SBO diets were greater thanin AT, the difference was not statistically significant ($P > 0.05$). SBO had larger quantities of linolenic acid ($P < 0.05$) than BT, which was reflected in the samples of all the tissues Morgan et al., (1992).

Interestingly the relative concentration of C18:3n3 (ALA) in adipose tissues of pigs fed the SFO diet (1.01) was lower ($P < 0.05$) than that of pigs fed the AT diet (1.19), as expected based on the concentrations of it in the experimental diets (1.42 and 1.6 respectively) Mitchaothai et al., (2007).

C20:3 n-3 levels were substantially higher in samples from animals fed plant-based diets than in those from animal-based diets Morel et al., (2013).

2. Fish Oil (FO)

Table 4.2.3 Summarizing statistical values of PUFA observed in pigs fed FO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
PUFA diet	6	46.40	7.49	33.10	55.90				
PUFA sc	6	20.38	3.43	16.86	25.17	20.11	0.0057	0.02	0.013

sc = subcutaneous fat.

Fish oil diets had one of the highest PUFA mean percentage (46.4) (Table 4.2.3) only after diets like sunflower oil (46.8%) (Table 4.4.3) but still lesser than soyabean oil diet (54.72 %) (Table 4.3.3) and linseed oil diet (56.01%) (Table 4.5.3). Fish oil had slightly higher PUFA mean SC than SFO (20.38 % and 19.25 %). Though having a lesser mean PUFA diet compared to SBO and LO, FO had greatest increase in regression intercept (20.11%) for PUFA SC indicating it was more effectively incorporating PUFA into SC than any other diets.

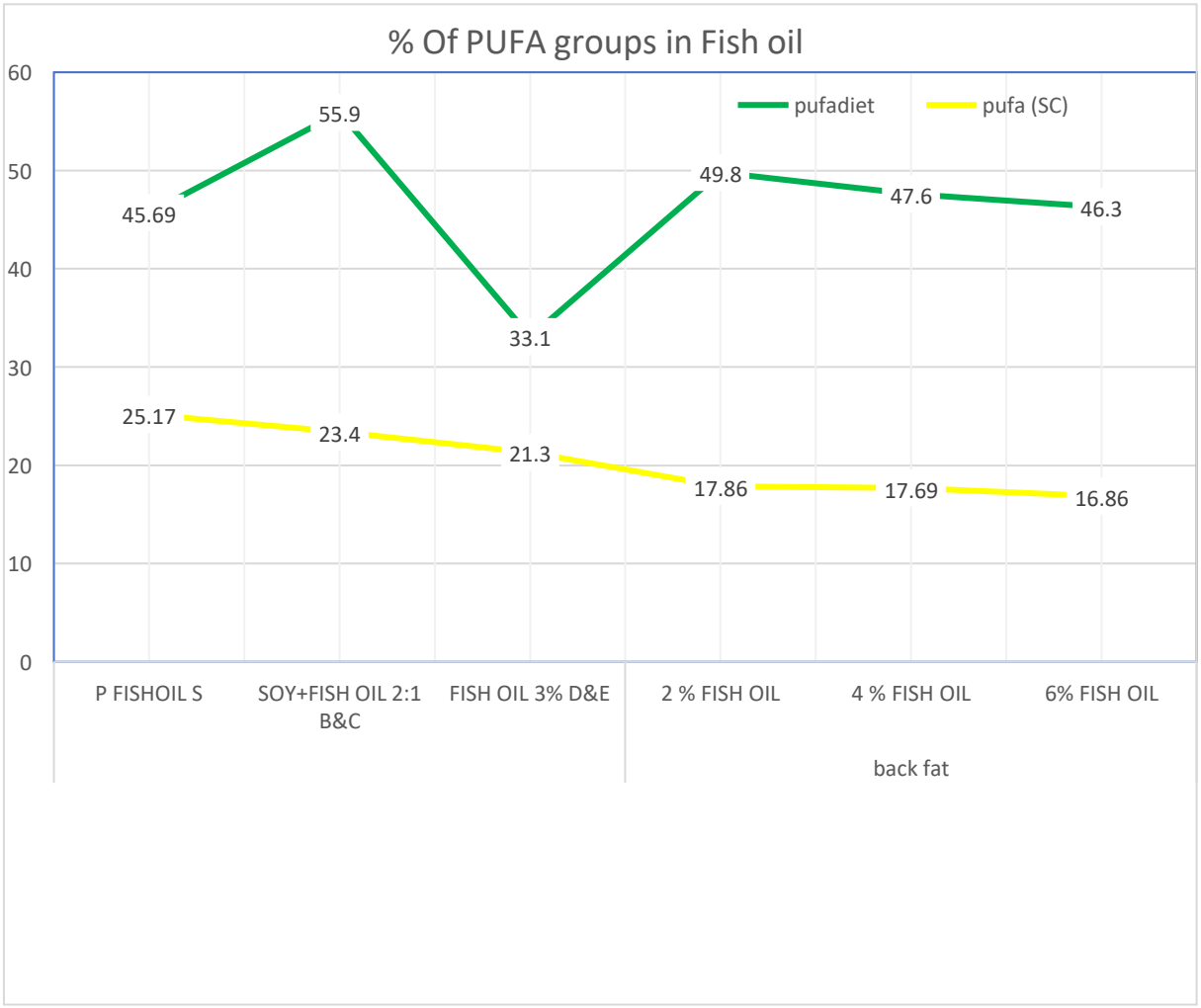

Figure 4.2.3 Summarizing the varying percentage of PUFA in fat tissues compared to their diets in Fish oil fed pigs.

Summarizing Figure 4.2.3, highest PUFA in fish oil diets (55.9%) has been reported by Øverland et al., (1996), who used a blend of soya oil and fish oil which might be the reason for this high level compared to other fish oil diets alone, as we know that soya oil is also a rich source of PUFA.

Changes in FA profile

Øverland et al., (1996) observed fish oil supplementation increased the concentrations of the fatty acids EPA, DPA and DHA in subcutaneous fat and muscle ($P<0.001$) while decreasing the concentration of the fatty acid LA in subcutaneous fat ($P < 0.001$). For subcutaneous fat, a regression analysis revealed that this effect was dose dependent ($P <0.001$).

According to Wood & Enser, (1997), higher ALA deposition could lead to enhanced EPA, DPA, and DHA synthesis via several desaturation and elongation processes. Supplementing the diet with fish oils, which are good suppliers of these fatty acids, is a more effective strategy to raise tissue concentrations of EPA and DHA Wood & Enser, (1997).

When fish oil (PFS) was replaced with tallow or vegetable oil in the diet, the levels of EPA, DPA, and DHA were 5 to 10 times lower, as expected Morel et al., (2013) since tallow supplementation increased SFA concentrations.

When pigs are fed a fish oil between 19 kg and 45 kg LW (PFSe) or 45 kg and 66 kg LW (PFSi), pork with greater levels of EPA, DPA, and DHA in the subcutaneous fat (3120 mg to 3740 mg per 100 g fat) can be produced, according to Morel et al., (2013).

Fish oil in diets increased long chain n-3 fatty acids in both subcutaneous fat and intramuscular fat Morel et al., (2013) as they are rich sources of these essential fatty acids.

The levels of EPA, DHA, DPA were 5 to 10 times higher when fish oil was replaced with tallow or vegetable oil Morel et al., (2013).

study supports the use of fishmeal as a dietary source of LC n-3 PUFA in the production of n-3-enriched pork. Furthermore, the enrichment was highly selective for DHA by feeding DHA-rich tuna fishmeal Howe, Downing, Grenyer, Grigonis, Deane, & Bryden, (2002)

Fish oil diets had 18.5% EPA and 11.2% DHA which are most important n-3 fatty acids in point of view of human health Øverland et al., (1996).

Fish oil had increased EPA, DPA at the expense of linoleic Øverland et al., (1996) and Oleic acid(Irie & Sakimoto, 1992) in sub cutaneous fat.

These authors also found a dose dependent effect of fish oil feeding on the concentrations of these fatty acids, which agree with Taugbøl, (1993) who reported an increase in the concentration of EPA, DPA and DHA in the fat tissue of pigs receiving up to 20 g fish oil in the diet.

Morgan et al., (1992) recommended a maximum 9.5 g/d of fish oil for optimum increase in fatty acids without causing any deleterious effects on meat quality.

Increased duration of feeding fish oil to pigs resulted in increased levels of EPA and DHA Irie & Sakimoto, (1992).

Previous research has shown that feeding fish oil to pigs results in significant enrichment of n-3 PUFA without compromising meat quality Irie & Sakimoto, (1992); Leskanich et al., 1997). Otten, Wirth, & Eichinger, (1993) supplemented with 5% fish oil for over 13 weeks and significantly increased (40–165 % higher) the relative amounts of n-3 fatty acid (EPA and DHA) in suckling pigs (fed with 5 % coconut oil). For direct n-3 PUFA enrichment of pork, fishmeal is a cheaper and more plentiful source than fish oil.

Leskanich, Noble, & Morgan, (1993) discovered that feeding fish oil for 6, 4, and 2 weeks before slaughter had a duration-dependent effect on the 20:5(n-3) and 22:6(n-3) content in the Phospholipids of the longissimus muscle.

Reduced fish oil leads to EPA and DHA reaching a plateau. Thus, it was efficient to introduce fish oil 4% for 2 weeks than to feed 2% fish oil for 4 weeks to deposit n3-PUFA in fats. n-3 deposition compromises oleic acid and linoleic acid depositions Irie & Sakimoto, (1992).

This suggests that the sensory profile is more affected by the length of time the diet is fed than by the total amount of fish oil used Øverland et al., (1996)

F.A. Ratio

While other dietary treatments had little effect on decreasing n-6: n-3 ratio to optimal level, fish oil had a remarkable impact in reducing the ratio which might be credited for its high levels of EPA, DHA and linolenic acid over n-6 group of FA.

The addition of fish oil to the diet has a significant impact on the n-6/n-3 fatty acid ratio Øverland et al., (1996). The following fatty acids were used to calculate the n-6/n-3 fatty acid ratio in fat and muscle tissue: 18:2n-6; 20:4n-6; 18:3n-3; 20:5n-3; 22:5n- 3; 22:6n-3. The ratio of n-6/n-3 decreased in the tissues of pigs given fish oil, as expected. In group A (pigs fed 3% soya oil), the n- 6/n-3 fatty acid ratio in fat and muscle tissue was 31.2 and 8.4, respectively, while in group E (pigs fed 3% fish oil), it was 1.7 and 1.6, respectively.

With the addition of fish oil to the diet, Morgan et al., (1992) discovered an increase in the ratio of n-6/n-3 fatty acids in muscle tissue (> 0.45), but only a slight increase in fat tissue.

Molecular lipid structure

18:2n-6 fatty acid is abundant in fish oil. For all groups, the concentration of 20: n-3, 22: n-3, and 22: 6n-3 fatty acids were higher in muscle tissue lipid than fat tissue. The concentration of n-3 fatty acids in muscle tissue increased more than in fat tissue in response to fish oil supplementation. This is most likely due to the fact that lipid in muscle tissue contains more phospholipids than lipid in subcutaneous fat tissue, and that the incorporation of polyunsaturated fatty acids into phospholipids takes precedence over incorporation into triacylglycerol Iritani & Narita, (1984).

Duration of feeding

Leskanich et al., (1993) demonstrated that feeding an unsaturated diet for a short period of time increased BF unsaturation.

The BF inner layer's eicosapentaenoic acid [20:5(n-3)] and docosahexaenoic acid [22:6(n-3)] content increased significantly as a result of feeding fish oil for 2, 4, or 6 weeks before slaughter in their feeding trial.

This is supported by Irie & Sakimoto, (1992) biopsy results, which used fish oil as the PUFA source, specifically 22:5(n-3) and 22:6. (n-3). Similarly, Wiseman & Agunbiade, (1998) and (Fontanillas et al., 1998) discovered that the most significant effect of diet occurs within 14 and 17 days, respectively. The 18:2(n-6) content of BF increased at a constant rate between 70 and 115 kg live weight, according to (Camoes, Mourot, Kouba, Cherot, & Mounier, 1995) which is consistent with the continuous rise in PUFA in BF biopsies taken after the first 2 weeks in the current study.

Changes in FA profile by Marine Algae (MA)

Additional to FO, DHA content of the LD muscle was significantly higher ($P < 0.01$) in all Marine algae (MA) groups than in the control group Sardi, Martelli, Lambertini, Parisini, & Mordenti, (2006).

The relative content of DHA in muscle tissue was found to be higher than that of subcutaneous fat, regardless of the dietary treatment.

F.A. Ratio

Alternatives such as MA based EPA and DHA manufacturing are too expensive and not a viable option from an economic standpoint.

In all MA treated groups, the ratio of n6 to n-3 PUFA in the loin was slightly reduced, with significant differences ($P < 0.05$) between the control group (A) (13.95) and group D (12.27). A similar reduction was observed in backfat, with significant differences ($P < 0.05$) between the control group (A) and group C (11.82) Sardi et al., (2006).

3. Soya Bean Oil (SBO)

Table 4.3.3 Summarizing statistical values of PUFA observed in pigs fed SBO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
PUFA diet	10	54.72	10.21	42.27	70.90				
PUFA sc	10	27.41	6.21	17.38	37.28	13.46	0.2250	17.59	0.419
PUFA lm	6	20.99	10.49	7.45	29.00	71.39	-0.9022	55.24	-0.743

sc = subcutaneous fat; lm = longissimus

Highest individual PUFA diet is noted in SBO diets (70.9%). SBO also had the second highest mean PUFA in diets (54.72%) just succeeding linseed oil diet (56.1%). A similar trend followed in the regression intercept of PUFA LM and PUFA SC with these diets. Though having lesser PUFA diet percentage, SBO displayed greatest mean percentage of PUFA SC and PUFA LM (27.41 and 20.99).

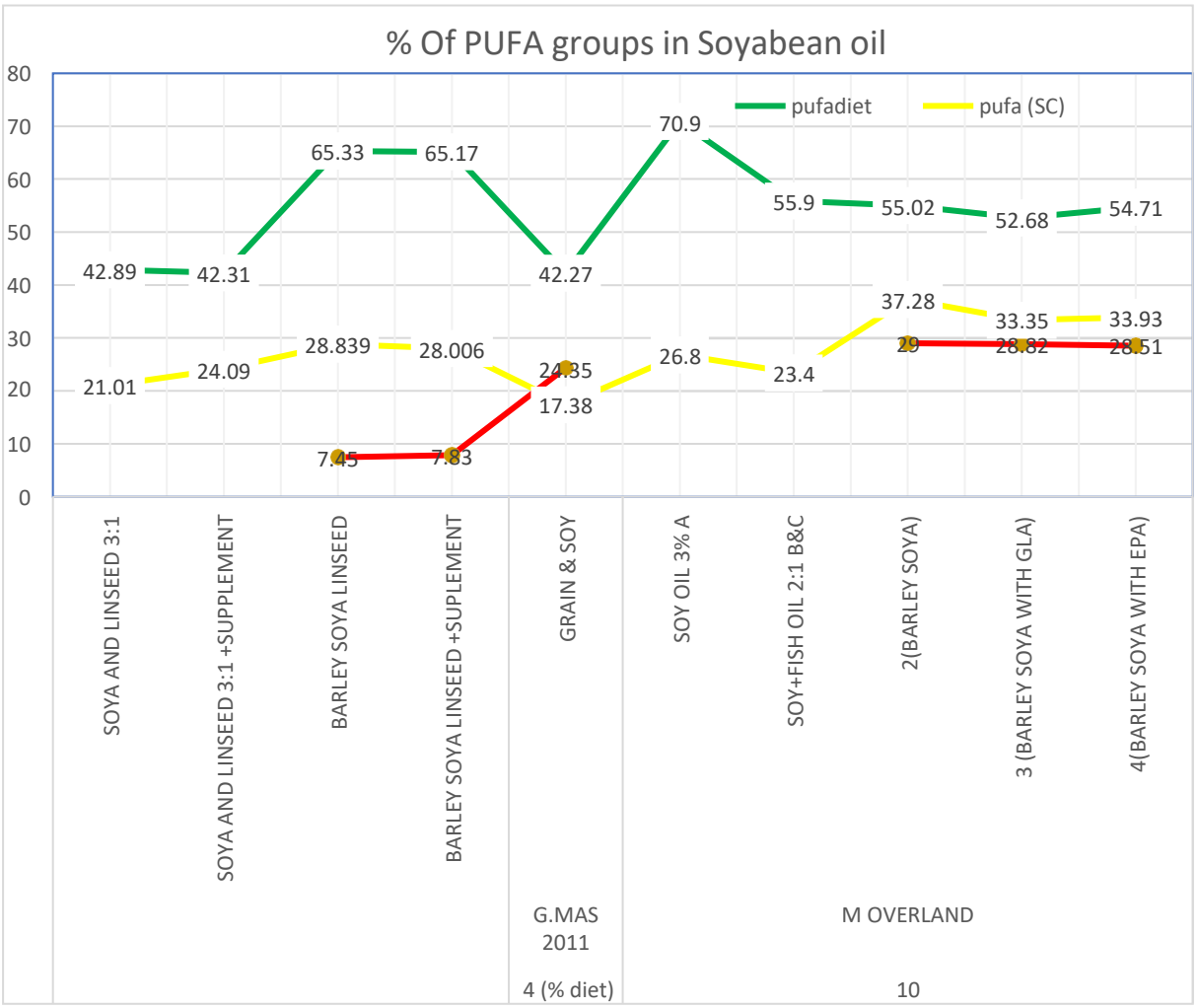

Figure 4.3.3 Summarizing the varying percentage of PUFA in fat tissues compared to their diets in Soyabean meal/oil fed pigs.

Summarizing Figure 4.3.3, PUFA LM was higher than PUFA SC in one study only Mas etal., (2011), while the rest of the studies had higher PUFA SC than PUFA LM.

Changes in FA profile

The high levels of linoleic acid (C18: 2) in diets 2 (soya oil), 3 (GLA oil) and 4 (EPA oil) reflect the effect of soya oil. Diet 3 had a small increase in total 18: 3 over diet 2 due to the addition of extra gamma linolenic acid (C18: 3 n-6) from the GLA oil. The addition of eicosapentaenoic acid (20:5) and docosahexaenoic acid (22:6) from EPA oil is visible in the diet 4 composition Morgan et al., (1992).

Eicosapentaenoic acid, an alpha linolenic acid metabolic product, was detected only in the pigs' samples offered by diet 4. It is probably a direct result of the introduction of EPA oil supplement containing eicosapentaenoic acid as a diet Morgan et al., (1992).

Soyabean is rich in linoleic acid (18:2) and linseed is rich in linolenic acid (18:3), so naturally diets having high percentage of soyabean result in high linoleic acid, arachidonic acid in fat tissues.

The soy oil 3% control diet given had increased stearic acid and linoleic acid (70.9%)

Replacement of AT with soyabean and linseed oil blend didn't increase levels of EPA, DPA and DHA Morel et al., (2013).

EPA was higher for plant diets due to more depots of linolenic acid Morel et al., (2006).

Linoleic acid was 25% more in plant-based diets which through biohydrogenation can increase production of CLA in animals Morel et al., (2013).

In diet 4, the percentage of EPA was nearly doubled when compared to the control group. The experimental groups had four- and three-times higher levels of EPA and DHA, respectively, than the control groups Morgan et al., (1992).

F.A. Ratio

Only PUFA diet (soya + linseed oil) resulted in favorable ratio for PUFA:SFA (0.61 with target >0.4) and ratio of linoleic acid to linolenic acid was 2.8 with target < 4 is of particular importance Morel et al., (2006).

The ratio of linoleic acid to α-linolenic acid, as well as the ratio of total (n-6) fatty acids to total (n-3) fatty acids, were significantly reduced in the muscle of pigs fed the experimental diets as a result of these changes ($P < .001$) Morgan et al., (1992)

Molecular lipid structure

Total fatty acid percentage was used as a covariate because of the pattern of fatty acid changes with elevated fat contents. This can be explained due to decrease in polar structured phospholipids relative to neutral lipids De Smet, Raes, & Demeyer, (2004); Morel et al., (2008).

4. Sunflower Oil (SFO)

Table 4.4.3 Summarizing statistical values of PUFA observed in pigs fed SFO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
pufa diet	4	46.8	26.1	9.5	69.8				
pufa sc	3	19.25	5.85	13.00	24.59	11.56	0.1967	75.51	0.869
pufa lm	3	13.17	4.99	9.90	18.91	10.37	0.0615	15.39	0.392

Sc = subcutaneous fat; lm = longissimus

SFO group alone had better increase in regression intercept for PUFA SC than PUFA LM with diet, with numerous diets having greater increase in PUFA LM than PUFA SC.

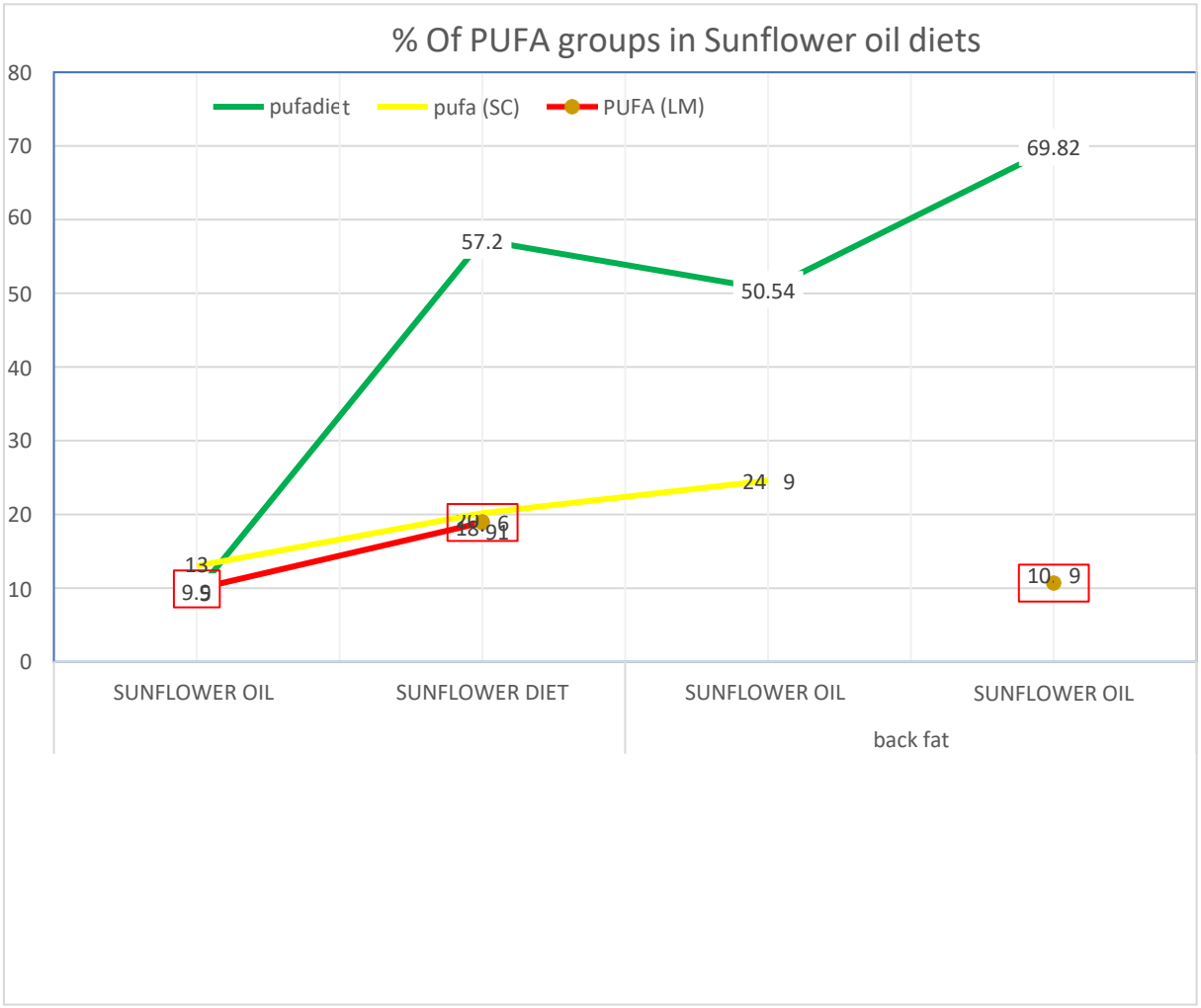

Figure 4.4.2 Summarizing the varying percentage of PUFA in fat tissues compared to their diets in sunflower oil fed pigs.

Summarizing Figure 4.4.2, an inconsistent pattern can be observed for PUFA in SFO diets. Miller et al., (1990) reported the lowest percentage PUFA (9.5%) among SFO diets since he used SFO rich in MUFA (80.9%).

Changes in fatty acid profile

The amount of polyunsaturated fat in the sunflower oil varied from 13.6 % in control to 13.8 % respectively which was the least increase reported among diets in Miller et al.,(1990) study.

The percentage of n-6 PUFA in adipose tissues of pigs fed a sunflower diet was greater (P< 0.01), owing to the greatest (P< 0.001) proportion of LA (17.95) and arachidonic acid (0.36%) Guillevic et al., (2009). But in the same research for n-3 PUFA, linseed oil has greater percentage in adipose tissue dominating SFO (5.27 and 0.81%) respectively.

Pigs fed the SFO diet had a larger percentage (0.27) of C20:4n-6 (arachidonic acid) in their adipose tissues Mitchaothai et al., (2007).

The percentage of n-6 PUFA in LM of pigs fed a sunflower diet was greater, owing to the greatest (P< 0.01) proportion of LA (8.53 %) and arachidonic acid (1.86 %) compared to CLA (6.38 and 1.44 %) respectively Eggert et al., (2001). But compared to SFO, CLA diets had higher percentage of Linolenic acid with former having 0.16% and latter 0.18% in the same study.

F.A. Ratio

The 18:2 n-6/18:3 n-3 ratios on the linseed diet (2.39) were significantly lower (P< 0.001) than on the sunflower diet (22.37) Guillevic et al., (2009).

The ratios of n-6/n-3 and C18:2n6/C18:3n3 were around two to three times greater in pigs given the SO diet than in pigs fed the BT diet in all tissues except erythrocytes Mitchaothai et al., (2007).

5. Linseed Oil (LO)

Table 4.5.3 Summarizing statistical values of PUFA observed in pigs fed LO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
PUFA diet	7	56.01	9.84	42.31	65.33				
PUFA sc	6	24.75	3.79	19.69	28.83	14.62	0.1840	25.76	0.508
PUFA lm	5	14.24	7.11	7.45	23.47	108.9	-1.543	90.8	-0.953

sc = subcutaneous fat; lm = longissimus

Linseed diet had the highest mean percentage PUFA content in diet (56.01) among all the dietary treatments. Despite having highest PUFA percentage diet, LO had lesser mean percentage of PUFA SC (24.75) and PUFA LM (14.24) compared to SBO (27.41 and 20.99) respectively. LO had greater increases in regression intercept of the tissues with diets compared to SBO. The largest negative correlation between diet and LM is seen in LO (-0.953).

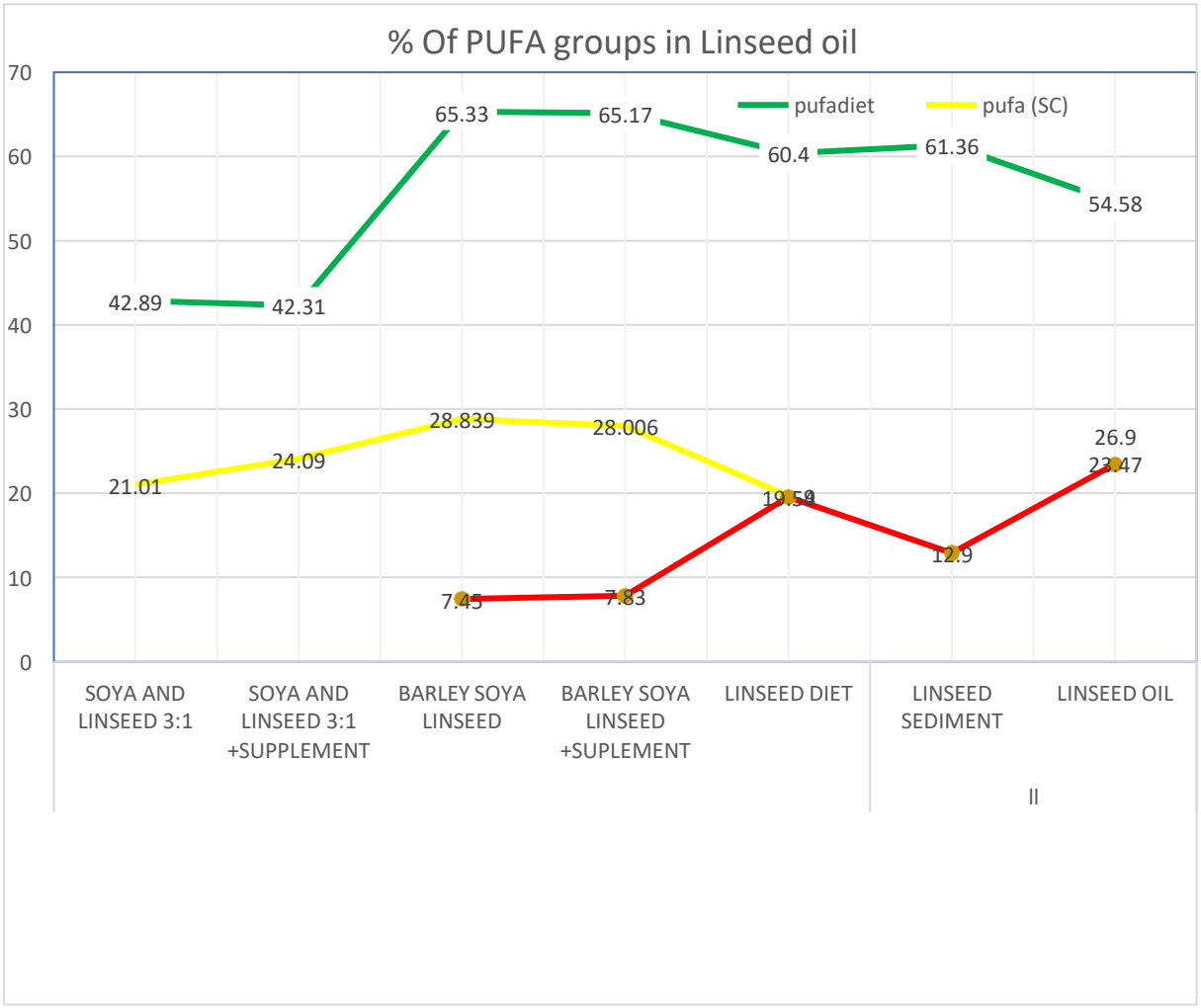

Figure 4.5.3 Summarizing the varying percentage of PUFA in fat tissues compared to their diets in linseed oil fed pigs.

Summarizing Figure 4.5.3, an inconsistent pattern can be noted, where PUFA SC and PUFA LM. Guillevic et al., (2009) reported similar values whereas in the rest of the treatments PUFA SC was greater than PUFA LM.

Linseed meal inclusion has technological advantages over the use of linseed oil because of its natural antioxidant content. Whole linseed, on the other hand, cannot be used in animal feed because the animal's digestive enzymes are unable to penetrate the seed coat. As a result, the seeds are broken by processes such as crushing, bruising, extrusion, or expansion to improve accessibility. The presence of linamarin, an antinutritional compound that can be destroyed

by thermo-extrusion technology, is another disadvantage of linseed that limits its use in diets. Linseed feeding has fewer negative effects on the risk of atherosclerosis and coronary thrombosis in humans associated with pig meat consumption.

Linseed Oil properties: -

- Enser et al., (2000); Matthews, Homer, Thies, & Calder, (2000) estimate that one-third of the oil in linseed and its by-products is 18:3 n-3.
- Linseed oil, as opposed to linseed meal, has been proven in numerous experiments to be more effective in raising the n-3 PUFA content in pig muscles Cherian & Sim, (1995).
- Rey et al., (2001) discovered that 0.5 % linseed oil increased intramuscular n-3 PUFA concentration significantly. Pig diets with 5% linseed oil enhanced n-3 PUFA content in muscles, heart, and back fat tissues without changing carcass composition or meat quality, according to Nuernberg et al., (2005); dietary linseed oil also considerably lowered the n-6/n-3 ratio Hoz et al., (2003).
- Because of its convenience and natural antioxidant content, feeding linseed has advantages over using oil Cunnane, Ganguli, Armstrong, & Stitt, (1990).
- Kouba, Enser, Whittington, Nute, & Wood, (2003) discovered that total n-3 PUFA andthe n-3/n-6 ratio increased in the muscles of pigs fed a 6 % crushed linseed diet for upto 100 days.
- Enser et al., (2000) reported that the dietary linseed increased the liver content, relativeto muscle, of both EPA (10-fold) and DHA (20-fold).
- The use of the linseed diet has already shown an increase in all of the PUFA n-3 levels, except in the DHA concentrations that did not vary in different tissues Raes, De Smet, & Demeyer, (2004). The review of Woods & Fearon, (2009) came to the same conclusion. At the expense of C20:4n-6, feeding 5 % linseed oil increased the

concentration of n-3 fatty acids in muscle, backfat, and heart tissue.

Changes in FA profile

The differences in PUFA levels in back fat (P <0.001) were due to higher levels of n-3 fatty acids, particularly 18:3n-3, which were 7 times higher than in pigs fed H (hydrogenated coconut oil) and 12 times higher than in pigs fed O (pomace oil) Fontanillas et al., (1997).

Other researchers have found levels of C18:3n-3 in adipose tissue of 5.80 % Cunnane et al., (1990)., 5.90 % in longissimus muscle, and 8.90 % in subcutaneous backfat. Cherian & Sim, (1995) used varied levels of linseed at levels of 26-27 % of C18:3n-3 in the diet. These values are lower than those in Fontanillas et al., (1997) (abdominal fat, 9.97 %; backfat, 11.36 %; longissimus muscle, 9.04 %), which could be attributable to differing levels of acid C18:3n-3 absorption in the small intestine depending on whether the n-3 comes from seeds or linseed oil. It's possible that linolenic acid digestion and absorption from seed is less efficient than from oil, because the latter has higher quantities of triglycerides, which are absorbed at a rate of more than 95% Nelson & Ackman, (1988).

The lower levels of arachidonic and docosatetraenoic acids reported in Fontanillas et al., (1997) (P <0.05) suggest that competition for the synthesis of n-6 and n-3 derivatives by their precursors, C18:2n-6 and C18:3n-3, occurred. Both the n-6 and n-3 families of fatty acids share the same enzyme for the synthesis of their derivatives. The enzyme Δ6 desaturase is responsible for the synthesis of arachidonic acid, an n-6 derivative, and eicosapentaenoic acid, an n-3 derivative. The increase in linolenic acid levels may cause the enzyme's activity to shift to the synthesis of its derivative, resulting in a decrease in arachidonic acid levels Fontanillas et al., (1997). Desaturase and elongase appear to be more concerned with the production of n-3 fatty acid metabolites than with that of n-6 fatty acid metabolites.

The same thing could happen if you went from C20:5n-3 to C22:5n-3, which would be preferred over C20:4n-6 to C22:4n-6.

As porcine organisms cannot synthesize linoleic (C18:2n-6) and -linolenic (C18:3n-3) PUFA, the content of these fatty acids in meat is determined by their content in the feed Okrouhlá et al., (2013). Leikus et al., (2018) reported trials revealed a significant increase in α- linolenic (C18:3n-3), ecosatrienoic (C20:3n-3), and eicosapentaenoic (C20:5n-3) fatty acids in the meat of both treated groups, as expected. Other authors Enser et al., (2000); Gordana Kralik et al., (2010); Rey et al., (2004); Riley, Enser, Nute, & Wood, (2000) all reported that dietary linseed or linseed oil supplementation resulted in a significant increase in the fatty acids mentioned above.

The concentration of EPA was higher than that of DHA. This agrees with study by Bečková & Václavková, (2010); Riley et al., (2000) who added linseed or linseed oil to pig feed, but contradicts the study results of Cunnane et al., (1990).

Nuernberg et al., (2005) fed pigs with n-3 supplemented linseed oil during the growing-finishing period. Linseed oil supplementation decreased the amount of arachidonic acid in muscle while increased the amount of linoleic acid. This drop is most likely due to arachidonic acid peroxidation.

F.A. Ratio

On the linseed diet, the PUFA/SFA ratio was more than or equivalent to 0.4, and the n-6/n-3 PUFA ratio was much lower Bečková & Václavková, (2010).

The n-6/n-3 PUFA ratio was lowered by the linseed diet from 12.36 1.06 in the C (control) group to

3.83 0.23 in the L (linseed oil) group ($P < 0.01$). According to Rey et al., (2001) meat from pigs fed linseed oil-enriched diets had a larger amount of n-3 fatty acids, and the n-6/n-3 ratio was lowered by20%.

Monounsaturated and polyunsaturated fatty acid proportions were considerably altered. When pigs were fed a linseed oil diet, the n-6/n-3 PUFA ratio was drastically lowered (from 9.88 to 2.48) in an experiment done by D'Arrigo et al., (2002).

6. CLA additive diets

Table 4.6.3 Summarizing statistical values of PUFA observed in pigs fed CLA added diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
PUFA diet	5	37.70	14.81	25.86	62.97				
PUFA sc	4	14.470	0.369	14.100	14.980	13.64	0.0264	13.76	0.367
PUFA lm	5	12.348	2.206	8.600	14.250	17.07	-0.1253	70.74	-0.841

sc = subcutaneous fat; lm = longissimus

Relative to LO, CLA diets displayed highest negative correlation between diet and LM (-0.841)(Table 4.6.3).

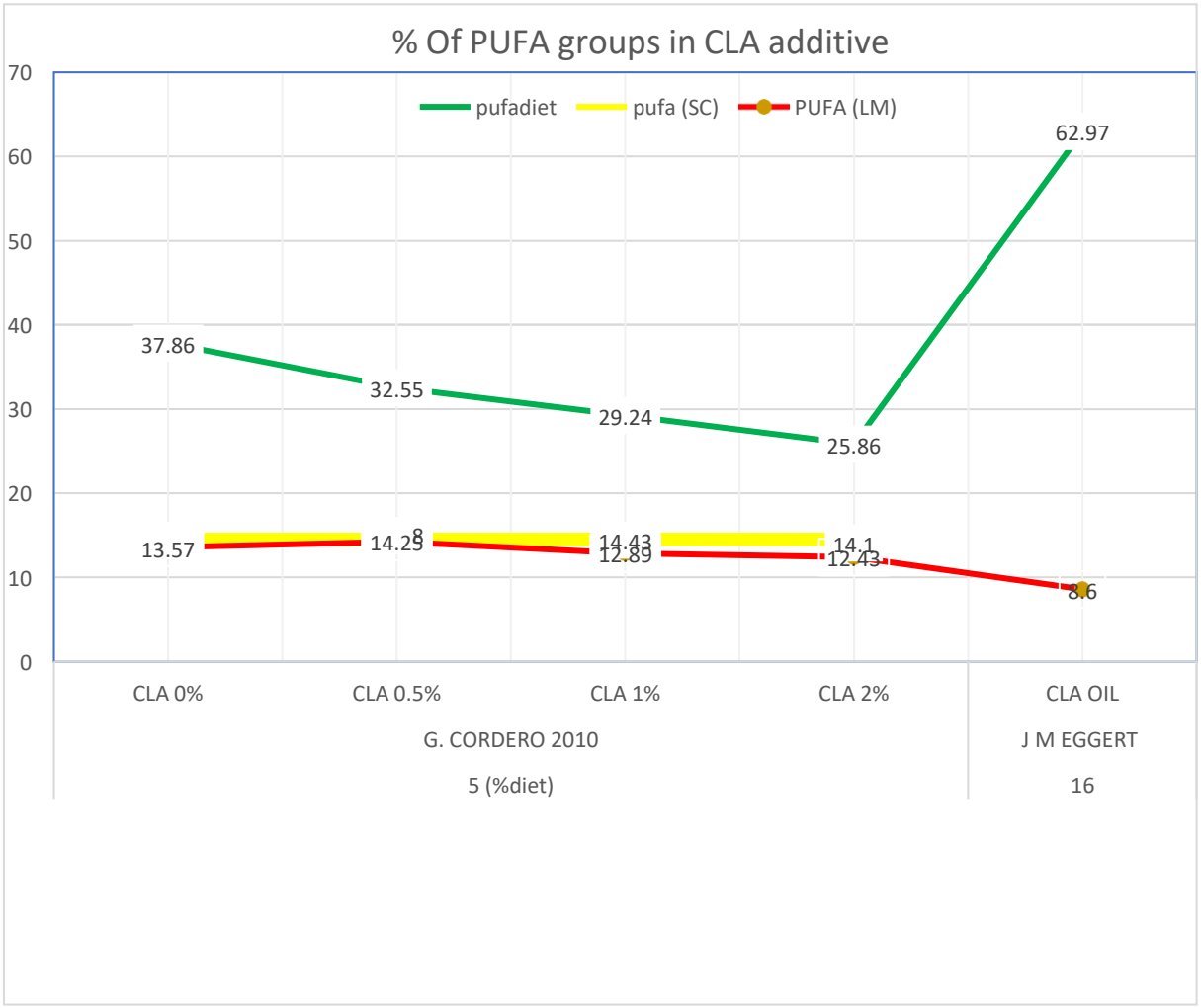

Figure 4.6.3 Summarizing the varying percentage of PUFA in fat tissues compared to their diets in CLA additive fed pigs.

Summarizing Figure 4.6.3, PUFA SC and PUFA LM were almost similar to each other. Eggert et al., (2001) reported the highest level of PUFA in diet but this diet also resulted in least percentage of PUFA LM causing the greatest dip in PUFA percentage.

Changes in fatty acid profile

According to Demaree et al., (2002) dietary CLA had no influence on the C18:2 n-6 concentration in IMF.

Cordero et al., (2010) inferred that the increase in PUFA proportion in subcutaneous backfat was related to an increase in C9, t11-CLA and t10, C12-CLA proportions since the C18:2 n-6 proportion was unaffected by dietary CLA and the C18:3 n-3 and C18:4 n-3 proportions decreased with dietary CLA enrichment. This is in line with past research Martin, Antequera, Gonzalez, Lopez-Bote, & Ruiz, (2007); Smith et al., (2002).

7. Special oils (SO)

Table 4.7.3 Summarizing statistical values of PUFA observed in pigs fed SO diets.

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
PUFA diet	9	35.67	12.79	19.40	55.90				
PUFA sc	6	15.883	2.021	13.100	18.000	12.93	0.1042	15.18	0.390
PUFA lm	9	16.59	6.04	10.27	27.00	13.89	0.0757	2.57	0.160

sc = subcutaneous fat; lm = longissimus

Like SFO, SO also had positive correlation between diet and fat tissues (Table 4.7.3).

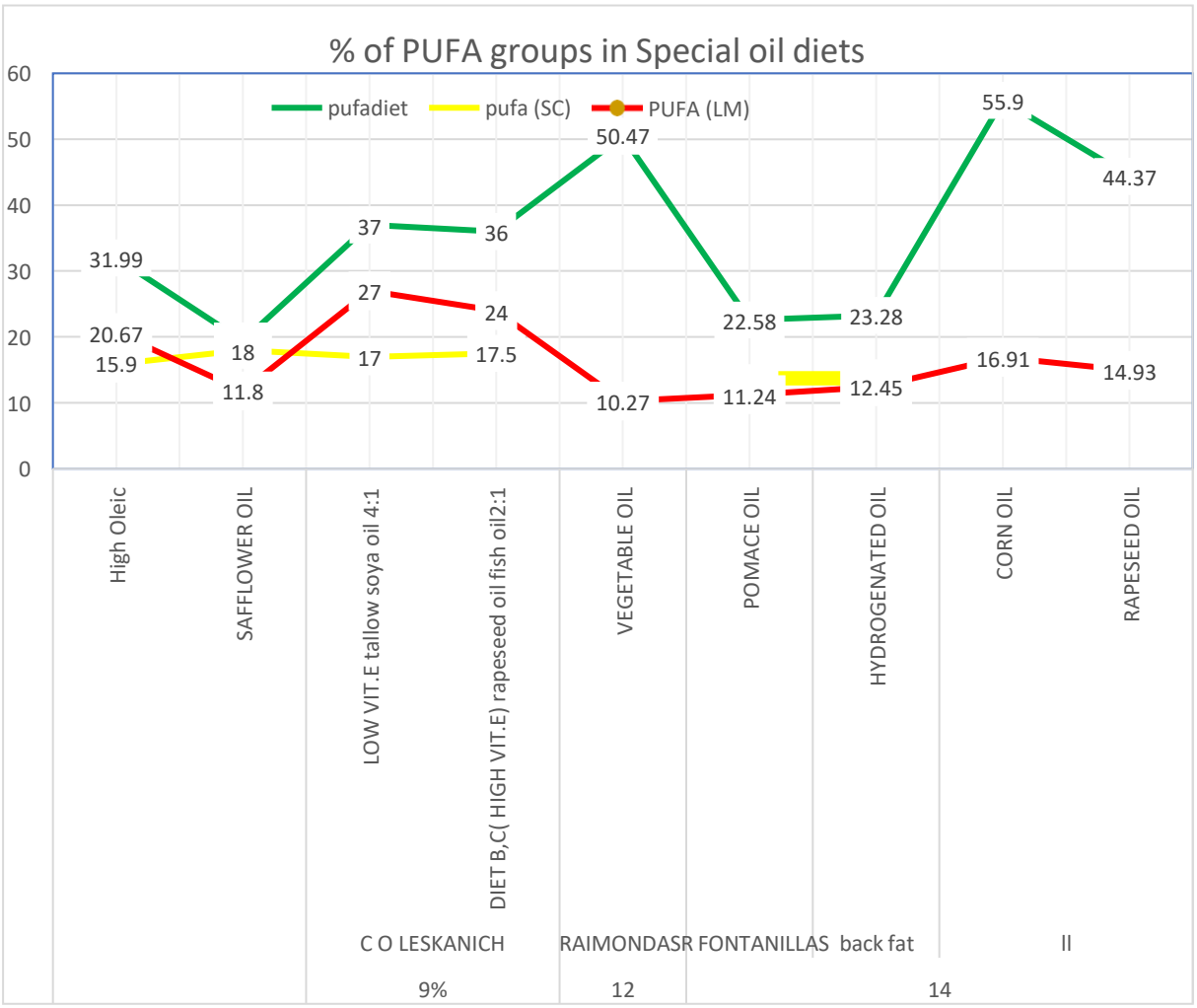

Figure 4.7.3 Summarizing the varying percentage of PUFA in fat tissues compared to their diets in Special oil fed pigs.

Summarizing Figure 4.7.3, an inconsistent pattern is presented because of the diverse diets forming this group. Second greatest dip in PUFA percentage between diet and PUFA LM was noted in vegetable oil Leikus et al., (2018). Highest PUFA LM values noted in special oil diets belongs to blends SBO and FO Leskanich et al., (1997).

Changes in fatty acid profile

The fatty acid contents of muscle and fat tissues changed dramatically. Because of the higher quantities of this fatty acid in the experimental meals, there were significant increases in a-linolenic acid levels Leskanich et al., (1997)

In pigs fed Diets B and C (rapeseed and fish oil blends), levels of (n-3) fatty acids such as linolenic acid, EPA, and DHA increased while levels of (n-6) fatty acids such as linoleic and arachidonic acids declined. In the experimental groups, the percentage of EPA was significantly doubled as compared to the control group. The ratios of linoleic acid to α-linolenic acid and total (n-6) fatty acids to total(n-3) fatty acids in the muscle of pigs fed the experimental diets were significantly lowered as a result of these alterations (P<.001) Leskanich et al., (1997).

He also reported the amounts of (n-3) fatty acids were significantly greater in the experimental groups (all P<.001), just as they were in the muscle. The experimental groups had three to four times higher amounts of EPA and DHA, respectively, than the control groups. But the proportions of total SFA and MUFA in the pigs fed the experimental diets were reduced (P< .05) and raised (P< .01), respectively, whereas the amount of total PUFA was unaltered Leskanich et al., (1997).

Fontanillas et al., (1997) used pomace oil, hydrogenated fat, and linseed oil as fat sources, and observed an exponential asymptotic response in BF fatty acid content due to manipulation of PUFA and MUFA contents of diets fed to pigs from 26 to 95 kg.

Kralik, Csapo, & Crnjac, (2006) discovered that feeding pigs 3 % or 6 % rapeseed oil enhanced DHA content in muscle tissue, indicating that pigs can synthesis DHA.

5 CHAPTER 5: General Overview

Our primary focus was to find about how lipid source of diet effects the FA concentration incorporation in fat tissues. The previous chapters showed that lipid source of diet significantly alters the FA composition in the fat tissues of pigs, but their effect seems insignificant in increasing FA concentration in these tissues. However, when considering all the data we noticed a stronger relationships between classes of dietary FA and fat tissue FA.

The relationships between dietary FA and FA in Sc and Loin are shown in Table 5.1, 5.2 and 5.3, for the SFA, MUFA and PUFA, respectively. The individual data points are represented in Figures 5.1, 5.2, 5.3, 5.4, 5.5 and 5.6, for the SFA, MUFA and PUFA, respectively.

Table 5.1 Summarizing Statistics of all the diets represented in above mentioned tables (SFA as whole)

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
SFA diet	48	22.89	10.15	6.78	52.92				
SFA sc	41	35.227	5.844	23.570	47.360	28.33	0.2894	24.82	0.498
SFA lm	33	38.008	5.030	30.760	51.110	36.19	0.0851	2.67	0.164

sc = subcutaneous fat; lm = longissimus

Table 5.2 Summarizing Statistics of all the diets represented in above mentioned tables (MUFA as whole)

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
MUFA diet	48	31.04	13.97	1.20	80.90				
MUFA sc	41	42.52	6.91	29.53	62.30	29.98	0.3969	73.12	0.855
MUFA lm	33	44.96	5.96	34.71	55.60	41.46	0.1085	7.16	0.268

sc = subcutaneous fat; lm = longissimus

Table 5.3 Summarizing Statistics of all the diets represented in above mentioned tables (PUFA aswhole)

Variable	N	Mean	StDev	Minimum	Maximum	Regression intercept	Regression slope	R-SQ (%)	Correlation
PUFA diet	48	42.97	16.54	9.5	70.9				
PUFA sc	41	20.58	6.47	11.77	37.28	8.21	0.3009	58.98	0.768
PUFA lm	33	16.08	6.73	7.45	29	16.71	-0.014	0.15	-0.039

Sc = subcutaneous fat; lm = longissimus

The MUFA mean percentage in SC (42.52%) and LM (44.96%) (Table 5.2) were higher compared to what observed in SFA (35.22%, 38%) (Table 5.1) and PUFA (20.58%, 16.08%) (Table 5.3) respectively. We can conclude that MUFA were the most prominent FA present in both tissues.

Moreover, no lipid source displayed negative drop in MUFA mean percentage of tissues when compared to diets which clearly suggest that MUFA is dominant in terms of incorporation into SC and LM compared to SFA and PUFA.

SFA displayed greatest increase between mean diet percentage and fat tissues percentage (12.33, 15.11) in SC and LM respectively, while MUFA almost similar to it (11.48 %, 13.92 %). PUFA showed a greater decrease in FA percentage from diet to tissues (22.39, 26.89) %. These results explain clearly that though PUFA are the dominant FA observed in all diets, their content in tissues can never increase beyond their supplied percentage, since they can't be synthesized in pig's body as such like SFA and PUFA.

While comparing SFA and MUFA which were readily synthesized in pigs, MUFA displayed greater regression intercept, slope and better correlation coefficients which makes it the most prominent group of FA to incorporate into tissues. This is evident by noticing their higher mean percentage in SC and LM than the other groups by > 6-28 % which is huge and indicates that MUFAare preferentially absorbed into tissues at higher rate.

In comparison of different fat tissues, SFA and MUFA displayed greater mean percentage in LM whereas PUFA displayed greater mean percentage in SC.

Figures below help us visualize the correlation coefficients between diets and tissues presented in tables above. In Figure 5.3, MUFA SC displays best linear pattern and highlights with greatest no. of points falling on the line and around it. It was followed by PUFA SC in Figure 5.5 with many points falling on either side of the line. Figures 5.2, 5.4 and 5.6 symbolize the poor correlation between FA groups and diets in LM and it is understandable due to differences in molecular lipid structure between tissues.

Figure 5.1 Scatter plot and regression line between SFA diet (%) and SFA in subcutaneous fat (SC) (%).

Figure 5.2 Scatter plot and regression line between SFA diet (%) and SFA in longissimus (LM) (%).

Figure 5.3 Scatter plot and regression line between MUFA diet (%) and MUFA in subcutaneousfat (SC) (%).

Figure 5.4 Scatter plot and regression line between MUFA diet (%) and MUFA in longissimus (LM) (%).

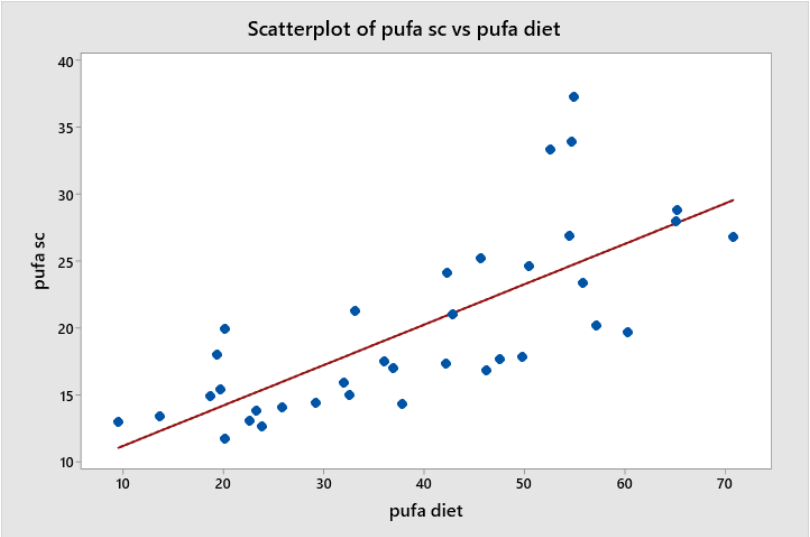

Figure 5.5 Scatter plot and regression line between PUFA (%) diet and PUFA in subcutaneous fat (SC) (%)

.

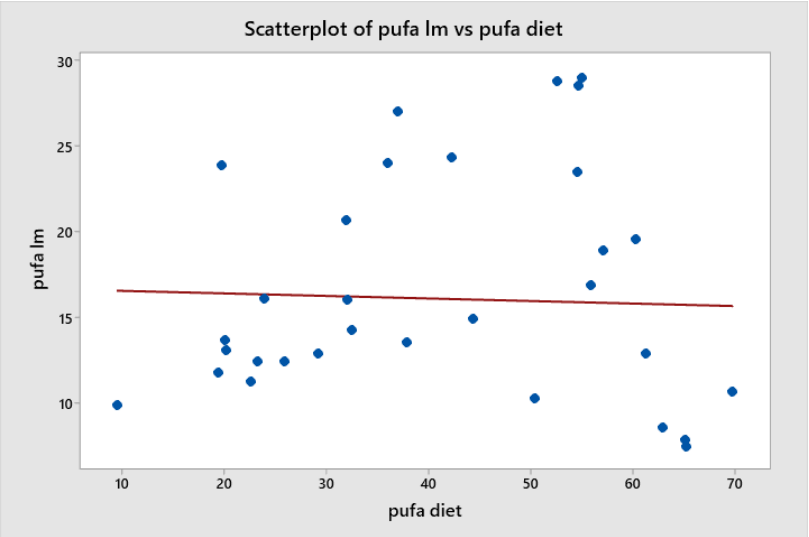

Figure 5.6 Scatter plot and regression line between PUFA diet (%) and PUFA in longissimus (LM) (%).

Overviewing SFA, AT is a rich source of SFA and had only increased SFA significantly in tissues and results of this review supports this statement (Table 4.1.1). But in our findings, CLA additive diets had the highest mean SFA percentage in SC (42.73) and LM (45.35) (Table 4.6.1) followed by linseed oil diet (Table 4.5.1), which were used as sources of PUFA until now. As we already know that SFA are believed to increase cholesterol content in human body, care should be taken to not include AT at higher rates since this group is made up of FA that can be readily metabolized in humans even if present in lower concentrations.

Coming to MUFA, we discovered that SFO and SO are rich sources of MUFA which was already discussed as the most prominent group among other FA groups to be incorporate into tissues Proving this SFO and SO remained the diets with higher mean MUFA percentage in SC andLM followed by AT.

Our primary target is to find out which lipid source is chiefly causing the greatest increase of PUFA in tissues since they are the most important in human health point of view. Though we already mentioned that FO is the best source of long chain PUFA, highest individual PUFA diet is noted in SBO diets (70.9%). SBO also had the second highest mean PUFA in diets (54.72%) just succeeding linseed oil diet (56.1%). A similar trend was observed in regression intercepts of PUFA LM and PUFA SC with these diets. Though having lesser PUFA diet percentage, SBO displayed greatest mean percentage of PUFA SC and PUFA LM (27.41 and 20.99).

To summarize the whole review, better PUFA content and their incorporation was witnessed in other lipid sources like SBO and LO, but the most important long chain PUFA like EPA, DPA and DHA are significantly increased with only FO. However, our world is becoming barren because of our ever-increasing population and the resulting increase in need for new foodsources. Seas and oceans which contribute to 70 % of mass on our planet have become breeding grounds for illegal commercial fishing, which had created mass extinction of marine life and pushed many species to endangered status. This causes a huge toll on earth's ecology and causes an imbalance in ocean life which can be fatal for future generations. To counter all this crisis, we need to come forward to implement certain policies and invent strategies to reduce and restrict fish oil use in livestock rearing since livestock farms already produce huge amounts of methane which increases global warming. This forces us to shift towards livestock rearing practices without causing irreversible damage to earth. Finally, findings of this review suggest that Plant-based oils are better increasing overall PUFA percentage compared to FO and can be the next best sources to increase important n-3 and are the viable alternative to the fast-depleting marine sources. The article by Toppe, (2011) reported from research studying plant-based oils generated from genetically modified plant seed oil can contain up to 15% DHA.

Overall, we found that the relationships between dietary FA acid and fat tissues FA was higher for the subcutaneous fat than the loin fat. In the subcutaneous fat 79 % of the variation in the MUFA content is explained by the MUFA content of the diet, this percentage is 59 % for the PUFA and 25 % for the SF. Future research should focus on making. advances in finding alternate lipid sources which bring out better fatty acid composition in pork tissues without causing a huge toll on environment. This numerical review might be useful in finding information about the average effects of different lipid sources on fat tissues and how they vary among themselves.

6 References

Averette Gatlin, L., See, M., Hansen, J., Sutton, D., & Odle, J. (2002). The effects of dietary fat sources, levels, and feeding intervals on pork fatty acid composition. *Journal of animal science, 80*(6), 1606-1615.

Bečková, R., & Václavková, E. (2010). The effect of linseed diet on carcass value traits and fatty acid composition in muscle and fat tissue of fattening pigs. *Czech Journal of Animal Science, 55*(8), 313-320.

Bourdon, J., Bazinet, T., Arnason, T., Kimpe, L., Blais, J., & White, P. (2010). Polychlorinated biphenyls (PCBs) contamination and aryl hydrocarbon receptor (AhR) agonist activity of Omega-3 polyunsaturated fatty acid supplements: implications for daily intake of dioxins and PCBs. *Food and Chemical Toxicology, 48*(11), 3093-3097.

Cameron, N., & Enser, M. (1991). Fatty acid composition of lipid in longissimus dorsi muscle of Duroc and British Landrace pigs and its relationship with eating quality. *Meat science, 29*(4), 295-307.

Camoes, J., Mourot, J., Kouba, M., Cherot, P., & Mounier, A. (1995). Effets de régimes ateneurs variables en acide linoléique sur les caractéristiques des tissus adipeux. *Journ. Rech. Porcine France, 27*, 291-296.

Cherian, G., & Sim, J. S. (1995). Dietary. alpha.-linolenic acid alters the fatty acid composition of lipid classes in swine tissues. *Journal of Agricultural and Food Chemistry, 43*(11), 2911-2916.

Christensen, K., & Goel, V. (1972). The influence of various glucose and insulin concentrations on in vitro lipid synthesis by adipose tissue isolated from adult pigs. *International Journal of Biochemistry, 3*(17), 591-597.

Christensen, K. D. (1963). Various fatty acids in fat tissues of pigs of the Danish Landrace fed with coconut fat or soybean oil. *Acta Agriculturae Scandinavica, 13*(3), 249-258.

Coates, W., & Ayerza, R. (2009). Chia (Salvia hispanica L.) seed as an n-3 fatty acid source for finishing pigs: effects on fatty acid composition and fat stability of the meat and internal fat, growth performance, and meat sensory characteristics. *Journal of animal science, 87*(11), 3798-3804.

Cordero, G., Isabel, B., Menoyo, D., Daza, A., Morales, J., Piñeiro, C., & López-Bote, C. (2010). Dietary CLA alters intramuscular fat and fatty acid composition of pig skeletal muscle and subcutaneous adipose tissue. *Meat science, 85*(2), 235-239.

Corino, C., Magni, S., Pagliarini, E., Rossi, R., Pastorelli, G., & Chiesa, L. (2002). Effects of dietary fats on meat quality and sensory characteristics of heavy pig loins. *Meat science, 60*(1), 1-8.

Cunnane, S. C., Ganguli, S., Armstrong, J. K., & Stitt, P. A. (1990). Raised omega-3 fatty acid levels in pigs fed flax. *Canadian Journal of Animal Science, 70*(1), 251-254.

Czernichow, S., Thomas, D., & Bruckert, E. (2010). n-6 Fatty acids and cardiovascular health: a review of the evidence for dietary intake recommendations. *British journal of Nutrition, 104*(6), 788-796.

D'Arrigo, M., Hoz, L., Lopez-Bote, C., Cambero, I., Pin, C., Rey, A., & Ordonez, J. (2002). Effect of dietary linseed oil and α-tocopherol on selected properties of pig fat. *Canadian Journal of Animal Science, 82*(3), 339-346.

Daza, A., Olivares, A., Rey, A., Latorre, M., Callejo, A., & López Bote, C. (2017). *Fatty acid composition of different adipose tissues in heavy pigs*.

De Smet, S., Raes, K., & Demeyer, D. (2004). Meat fatty acid composition as affected by fatness and genetic factors: a review. *Animal Research, 53*(2), 81-98.

Dean, H. K., & Hilditch, T. P. (1933). The body fats of the pig: The influence of body temperature on the composition of depot fats. *Biochemical Journal, 27*(6), 1950-1956.

Demaree, S. R., Gilbert, C. D., Mersmann, H. J., & Smith, S. B. (2002). Conjugated linoleic acid differentially modifies fatty acid composition in subcellular fractions of muscle and adipose tissue but not adiposity of postweanling pigs. *The Journal of nutrition, 132*(11), 3272-3279.

Eggert, J., Belury, M., Kempa-Steczko, A., Mills, S., & Schinckel, A. (2001). Effects of conjugated linoleic acid on the belly firmness and fatty acid composition of genetically lean pigs. *Journal of animal science, 79*(11), 2866-2872.

Enser, M., Richardson, R., Wood, J., Gill, B., & Sheard, P. (2000). Feeding linseed to increase the n-3 PUFA of pork: fatty acid composition of muscle, adipose tissue, liver and sausages. *Meat science, 55*(2), 201-212.

Fontanillas, R., Barroeta, A., Baucells, M., & Codony, R. (1997). Effect of feeding highly cis-monounsaturated, trans, or n− 3 fats on lipid composition of muscle and adipose tissue of pigs. *Journal of Agricultural and Food Chemistry, 45*(8), 3070-3075.

Fontanillas, R., Barroeta, A., Baucells, M., & Guardiola, F. (1998). Backfat fatty acid evolution in swine fed diets high in either cis-monounsaturated, trans, or (n-3) fats. *Journal of animal science, 76*(4), 1045-1055.

Girard, J., Bout, J., & Salort, D. (1988). *Lipids and qualities of pork adipose and muscular tissues. Factors of variation. 1rst Part: Lipids and qualities of adipose tissue. Factors of variation.* Paper presented at the Annales de zootechnie.

Givens, D. I., & Gibbs, R. A. (2008). Current intakes of EPA and DHA in European populations and the potential of animal-derived foods to increase them: Symposium on 'How can the n-3 content of the diet be improved?'. *Proceedings of the Nutrition Society, 67*(3), 273-280.

Guillevic, M., Kouba, M., & Mourot, J. (2009). Effect of a linseed diet or a sunflower diet on performances, fatty acid composition, lipogenic enzyme activities and stearoyl-CoA-desaturase activity in the pig. *Livestock Science, 124*(1-3), 288-294.

Gurr, M., & James, A. (1980). Fatty acids. In *Lipid biochemistry: An introduction* (pp. 18-89): Springer.

Hibbeln, J. R., Nieminen, L. R., Blasbalg, T. L., Riggs, J. A., & Lands, W. E. (2006). Healthy intakes of n− 3 and n–6 fatty acids: estimations considering worldwide diversity. *The American journal of clinical nutrition, 83*(6), 1483S-1493S.

Howe, P. R., Downing, J. A., Grenyer, B. F., Grigonis-Deane, E. M., & Bryden, W. L. (2002). Tuna fishmeal as a source of DHA for n− 3 PUFA enrichment of pork, chicken, and eggs. *Lipids, 37*(11), 1067-1076.

Hoz, L., Lopez-Bote, C., Cambero, M., D'Arrigo, M., Pin, C., Santos, C., & Ordóñez, J. (2003). Effect of dietary linseed oil and α-tocopherol on pork tenderloin (Psoas major) muscle. *Meat science, 65*(3), 1039-1044.

Irie, M., & Sakimoto, M. (1992). Fat characteristics of pigs fed fish oil containing eicosapentaenoic and docosahexaenoic acids. *Journal of animal science, 70*(2), 470-477.

Iritani, N., & Narita, R. (1984). Changes of arachidonic acid and n-3 polyunsaturated fatty acids of phospholipid classes in liver, plasma and platelets during dietary fat manipulation. *Biochimica et biophysica acta, 793*(3), 441-447.

Jakobsen, K., & Thorbek, G. (1991). *The respiratory quotient in relation to fat retention from car-bohydrates or lipids in growing pigs.* Paper presented at the 12th Symposium on Energy Metabolism of Farm Animais (C Wenk, M Boessinger, eds) Kar-tause, Ittingen, CH.

Jump, D. B. (2002). Dietary polyunsaturated fatty acids and regulation of gene transcription. *Current opinion in lipidology, 13*(2), 155-164.

Kitz, R., Rose, M. A., Schubert, R., Beermann, C., Kaufmann, A., Böhles, H. J., . . . Zielen, S. (2010). Omega-3 polyunsaturated fatty acids and bronchial inflammation in grass pollen allergy after allergen challenge. *Respiratory medicine, 104*(12), 1793-1798.

Koch, D., Parr, A., & Merkel, R. (1968). Fatty acid composition of the inner and outer layers of porcine backfat as affected by energy level, sex and sire. *Journal of Food Science, 33*(2), 176-180.

Koch, D. E., Pearson, A., Magee, W., Hoefer, J., & Schweigert, B. (1968). Effect of diet on the fatty acid composition of pork fat. *Journal of animal science, 27*(2), 360-365.

Kouba, M., Enser, M., Whittington, F., Nute, G., & Wood, J. (2003). Effect of a high-linolenic acid diet on lipogenic enzyme activities, fatty acid composition, and meat quality in the growing pig. *Journal of animal science, 81*(8), 1967-1979.

Kouba, M., & Mourot, J. (1999). Effect of a high linoleic acid diet on lipogenic enzyme activities and on the composition of the lipid fraction of fat and lean tissues in the pig. *Meat science, 52*(1), 39-45.

Kralik, G., Csapo, J., & Crnjac, T. (2006). Feeding rapeseed oil to increase n-3 PUFA of pork: fatty acid composition of muscle and adipose tissue. *Acta alimentaria, 35*(3), 251-258.

Kralik, G., Margeta, V., Suchý, P., & Straková, E. (2010). Effects of dietary supplementation with rapeseed and linseed oil on the composition of fatty acids in porcine muscle tissue. *Acta Veterinaria Brno, 79*(3), 363-367.

Lee, K. N., Pariza, M. W., & Ntambi, J. M. (1998). Conjugated linoleic acid decreases hepatic stearoyl-CoA desaturase mRNA expression. *Biochemical and biophysical research communications, 248*(3), 817-821.

Leikus, R., Juskiene, V., Juska, R., Juodka, R., Stankeviciene, D., Nainiene, R., & Siukscius, A. (2018). Effect of linseed oil sediment in the diet of pigs on the growth performance and fatty acid profile of meat. *Revista Brasileira de Zootecnia, 47*

Leskanich, C., Matthews, K., Warkup, C., Noble, R., & Hazzledine, M. (1997). The effect of dietary oil containing (n-3) fatty acids on the fatty acid, physicochemical, and organoleptic characteristics of pig meat and fat. *Journal of animal science, 75*(3), 673-683.

Leskanich, C., Noble, R., & Morgan, C. (1993). Effect of long-chain dietary polyunsaturated fatty acid content on pig meat. *Proceedings of the British Society of Animal Production (1972), 1993*, 11-11.

Leszczynski, D., Pikul, J., Easter, R., McKeith, F., McLaren, D., Novakofski, J., . . . Jewell, D. (1992). Characterization of lipid in loin and bacon from finishing pigs fed full-fat soybeans or tallow. *Journal of animal science, 70*(7), 2175-2181.

Leymaster, K., & Mersmann, H. (1991). Effect of limited feed intake on growth of subcutaneous adipose tissue layers and on carcass composition in swine. *Journal of animal science, 69*(7), 2837-2843.

Leyton, J., Drury, P., & Crawford, M. (1987). Differential oxidation of saturated and unsaturated fatty acids in vivo in the rat. *British journal of Nutrition, 57*(3), 383-393.

López-Bote, C., Isabel, B., & Daza, A. (2002). Partial replacement of poly-with monounsaturated fatty acids and vitamin E supplementation in pig diets: effect on fatty acid composition of subcutaneous and intramuscular fat and on fat and lean firmness. *Animal Science, 75*(3), 349-358.

Mahaffey, K. R., Clickner, R. P., & Jeffries, R. A. (2008). Methylmercury and omega-3 fatty acids: co-occurrence of dietary sources with emphasis on fish and shellfish. *Environmental Research, 107*(1), 20-29.

Martin, D., Antequera, T., Gonzalez, E., Lopez-Bote, C., & Ruiz, J. (2007). Changes in the fatty acid profile of the subcutaneous fat of swine throughout fattening as affected by dietary conjugated linoleic acid and monounsaturated fatty acids. *Journal of Agricultural and Food Chemistry, 55*(26), 10820-10826.

Mas, G., Llavall, M., Coll, D., Roca, R., Díaz, I., Oliver, M., . . . Realini, C. (2011). Effect of an elevated monounsaturated fat diet on pork carcass and meat quality traits and tissue fatty acid composition from York-crossed barrows and gilts. *Meat science, 89*(4), 419-425.

Matthews, K., Homer, D., Thies, F., & Calder, P. (2000). Effect of whole linseed (Linum usitatissimum) in the diet of finishing pigs on growth performance and on the qualityand fatty acid composition of various tissues. *British journal of Nutrition, 83*(6), 637-643.

Miller, M., Shackelford, S., Hayden, K., & Reagan, J. (1990). Determination of the alteration in fatty acid profiles, sensory characteristics and carcass traits of swine fed elevated levels of monounsaturated fats in the diet. *Journal of animal science, 68*(6), 1624-1631.

Mitchaothai, J., Yuangklang, C., Wittayakun, S., Vasupen, K., Wongsutthavas, S., Srenanul, P., . . . Beynen, A. (2007). Effect of dietary fat type on meat quality and fatty acid composition of various tissues in growing–finishing swine. *Meat science, 76*(1), 95-101.

Morel, P., Janz, J., Zou, M., Purchas, R., Hendriks, W., & Wilkinson, B. (2008). The influence of diets supplemented with conjugated linoleic acid, selenium, and vitamin E, with or without animal protein, on the composition of pork from female pigs. *Journal of animal science, 86*(5), 1145-1155.

Morel, P., McIntosh, J., & Janz, J. (2006). Alteration of the fatty acid profile of pork by dietary manipulation. *Asian-australasian journal of animal sciences, 19*(3), 431-437.

Morel, P. C., Leong, J., Nuijten, W. G., Purchas, R. W., & Wilkinson, B. H. (2013). Effect of lipid type on growth performance, meat quality and the content of long chain n− 3 fatty acids in pork meat. *Meat science, 95*(2), 151-159.

Morgan, C. A., Noble, R. C., Cocchi, M., & McCartney, R. (1992). Manipulation of the fatty acid composition of pig meat lipids by dietary means. *Journal of the Science of Food and Agriculture, 58*(3), 357-368.

Myer, R., Johnson, D., Knauft, D., Gorbet, D., Brendemuhl, J., & Walker, W. (1992). Effect of feeding high-oleic-acid peanuts to growing-finishing swine on resulting carcass fatty acid profile and on carcass and meat quality characteristics. *Journal of animal science, 70*(12), 3734-3741.

Nelson, G. J., & Ackman, R. G. (1988). Absorption and transport of fat in mammals with emphasis on n− 3 polyunsaturated fatty acids. *Lipids, 23*(11), 1005-1014.

Nguyen, L., Nuijens, M., Everts, H., Salden, N., & Beynen, A. (2003). Mathematical relationships between the intake of n-6 and n-3 polyunsaturated fatty acids and their contents in adipose tissue of growing pigs. *Meat science, 65*(4), 1399-1406.

Nuernberg, K., Fischer, K., Nuernberg, G., Kuechenmeister, U., Klosowska, D., Eliminowska-Wenda, G., . . . Ender, K. (2005). Effects of dietary olive and linseed oil on lipid composition, meat quality, sensory characteristics and muscle structure in pigs. *Meat science, 70*(1), 63-74.

Okrouhlá, M., Stupka, R., Čítek, J., Šprysl, M., & Brzobohatý, L. (2013). Effect of dietary linseed supplementation on the performance, meat quality, and fatty acid profile of pigs. *Czech Journal of Animal Science, 58*(6), 279-288.

Otten, W., Wirth, C., & Eichinger, H. M. (1993). A high omega-3 fatty acid diet alters fatty acid composition of heart, liver, kidney, adipose tissue and skeletal muscle in swine. *Annals of nutrition and metabolism, 37*(3), 134-141.

Øverland, M., Taugbøl, O., Haug, A., & Sundstøl, E. (1996). Effect of fish oil on growth performance, carcass characteristics, sensory parameters, and fatty acid composition in pigs. *Acta Agriculturae Scandinavica A-Animal Sciences, 46*(1), 11-17.

Raes, K., De Smet, S., & Demeyer, D. (2004). Effect of dietary fatty acids on incorporation of long chain polyunsaturated fatty acids and conjugated linoleic acid in lamb, beef and pork meat: a review. *Animal feed science and technology, 113*(1-4), 199-221.

Rey, A., Kerry, J., Lynch, P., Lopez-Bote, C., Buckley, D., & Morrissey, P. (2001). Effect of dietary oils and α-tocopheryl acetate supplementation on lipid (TBARS) and cholesterol oxidation in cooked pork. *Journal of animal science, 79*(5), 1201-1208.

Rey, A., Lopez-Bote, C., Kerry, J., Lynch, P., Buckley, D., & Morrissey, P. (2004). Modification of lipid composition and oxidation in porcine muscle and muscle microsomes as affected by dietary supplementation of n-3 with either n-9 or n-6 fatty acids and α-tocopheryl acetate. *Animal feed science and technology, 113*(1-4), 223-238.
Rhee, K., Davidson, T., Cross, H., & Ziprin, Y. (1990). Characteristics of pork products from swine fed a high monounsaturated fat diet: Part 1—Whole muscle products. *Meat science, 27*(4), 329-341.
Riley, P., Enser, M., Nute, G., & Wood, J. (2000). Effects of dietary linseed on nutritional value and other quality aspects of pig muscle and adipose tissue. *Animal Science, 71*(3), 483-500.
Ruxton, C., Calder, P., Reed, S. C., & Simpson, M. (2005). The impact of long-chain n-3 polyunsaturated fatty acids on human health. *Nutrition research reviews, 18*(1), 113-129.
Sardi, L., Martelli, G., Lambertini, L., Parisini, P., & Mordenti, A. (2006). Effects of a dietary supplement of DHA-rich marine algae on Italian heavy pig production parameters. *Livestock Science, 103*(1-2), 95-103.
Sciences, H. D. o. P. (1994). *NIOSH, Manual of Analytical Methods*: US Department of Health and Human Services, Public Health Service, Centers ….
Simopoulos, A. P. (2002a). The importance of the ratio of omega-6/omega-3 essential fatty acids. *Biomedicine & pharmacotherapy, 56*(8), 365-379.
Simopoulos, A. P. (2002b). Omega-3 fatty acids in inflammation and autoimmune diseases. *Journal of the American College of nutrition, 21*(6), 495-505.
Smith, S., Hively, T., Cortese, G., Han, J., Chung, K., Castenada, P., . . . Mersmann, H. (2002). Conjugated linoleic acid depresses the Δ9 desaturase index and stearoyl coenzyme A desaturase enzyme activity in porcine subcutaneous adipose tissue. *Journal of animal science, 80*(8), 2110-2115.
St. John, L., Young, C., Knabe, D., Thompson, L., Schelling, G., Grundy, S. M., & Smith, S. (1987). Fatty acid profiles and sensory and carcass traits of tissues from steers and swine fed an elevated monounsaturated fat diet. *Journal of animal science, 64*(5), 1441-1447.
Taugbøl, O. (1993). Omega-3 Fatty Acid Incorporation in Fat and Muscle Tissues of Growing Pigs, Fed Supplements of Fish Oil. *Journal of Veterinary Medicine Series A, 40*(1-10), 93-101.
Thompson, E., & Allen, E. (1969). *Relationship between stearic acid desaturase and fatty acid composition.* Paper presented at the Journal of animal science.
Toppe, J. (2011). GLOBEFISH - Information and Analysis on World Fish Trade. Retrieved from http://www.fao.org/in-action/globefish/fishery-information/resource-detail/en/c/338773/
Van Deckel, M. J., Casteels, M., Warnants, N., Van Damme, L., & Boucque, C. V. (1996). Omega-3 fatty acids in pig nutrition: implications for the intrinsic and sensory quality of the meat. *Meat science, 44*(1-2), 55-63.
Vernon, R. G. (1992). Effects of diet on lipolysis and its regulation. *Proceedings of the Nutrition Society, 51*(3), 397-408.
Villegas, F. J., Hedrick, H., Veum, T., McFate, K., & Bailey, M. (1973). Effect of diet and breed on fatty acid composition of porcine adipose tissue. *Journal of animal science, 36*(4), 663-668.
Warnants, N., Van Oeckel, M., & Boucque, C. V. (1999). Incorporation of dietary polyunsaturated fatty acids into pork fatty tissues. *Journal of animal science, 77*(9), 2478-2490.
Wiseman, J., & Agunbiade, J. (1998). The influence of changes in dietary fat and oils on fatty acid profiles of carcass fat in finishing pigs. *Livestock Production Science, 54*(3), 217-227.
Wood, J. (1984). Fat deposition and the quality of fat tissue in meat animals. *Fats in animal nutrition, 41*, 407-435.
Wood, J., Enser, M., Fisher, A., Nute, G., Richardson, R., & Sheard, P. (1999). Manipulating meat quality and composition. *Proceedings of the Nutrition Society, 58*(2), 363-370.
Wood, J., Richardson, R., Nute, G., Fisher, A., Campo, M., Kasapidou, E., . . . Enser, M. (2004). Effects of fatty acids on meat quality: a review. *Meat science, 66*(1), 21-32.
Wood, J. D., & Enser, M. (1997). Factors influencing fatty acids in meat and the role of antioxidants in improving meat quality. *British journal of Nutrition, 78*(1), S49-S60.
Woods, V. B., & Fearon, A. M. (2009). Dietary sources of unsaturated fatty acids for animals and their transfer into meat, milk and eggs: A review. *Livestock Science, 126*(1-3), 1-20.
Calder, P. C. (2013). Omega-3 polyunsaturated fatty acids and inflammatory processes: nutrition or pharmacology? *British journal of clinical pharmacology, 75*(3), 645-662.