On farm

Fats & Oils

Alternative Energy Dense Feedstuffs for the Cattle Feedlot Industry – Phase 2.

FLOT.106

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Feedlots

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SUMMARY

Fats and oils are the most energy dense feedstuffs. Their chemical and physical properties can enhance ration quality and improve livestock performance in the major intensive livestock industries, where their supplemental use has increased in recent years.

Supplemental fats and oils are commonly used in the USA cattle feedlot industry, and their use has been commonplace in major sectors of the Australian feedlot industry since at least the early 1970s.

Feedgrade fats and oils are readily available in three forms: oilseeds, commodity fats and oils, and specialty fats. The commodity fats and oils, the subject of the study, include animal fats such as tallow or yellow grease, and blends of animal and vegetable fats. These are frequently available to the Australian feedlot industry at reasonable costs varying in relation to grade and location. Australia exports in the order of 65% of its commodity fats and oils, principally as the rendered end product tallow or grease, or, in a value added form. The intensive livestock industries consume an estimated 94,000 tonnes of which the feedlot industry uses 34,000 tonnes.

The oilseeds which include oils derived from seeds, are high in fat and commonly available at a reasonable cost. The specialty fats comprise fats treated to make them more ruminally inert. The treatments are expensive, but are claimed to enable their feeding at higher levels when the opportunities for feeding the usually more reasonably costed oilseeds and commodity fats and oils have been exhausted.

Commodity fats and oils are included in high concentrate feedlot finishing rations to increase dietary energy and cattle nutrient energy intake. Their inclusion enhances average daily gains, increases feed use efficiency, and improves carcase characteristics. There are also associated benefits which contribute significantly to an improved general overall operational efficiency.

The effectiveness with which fats and oils are used largely relates to their quality. Their feeding value and acceptability can be generally described in terms of the following characteristics.

- Purity — fat proportion and composition as it might affect nutrient energy value;
- Stability — rancidity as it might affect livestock acceptability;
- Contaminants — as they might affect animal health and meat products; and
- Consistency — delivery to delivery, as it might affect livestock acceptability.

The utilisation of supplemental fats and oils in beef cattle diets is a dynamic function of:

- level of supplementation, basal dietary fat levels and sources of fats;
- interaction with other ingredients and nutrients;
- interaction with the climatic environment;
- quality characteristics; and
- acceptability and/or palatability.

Supplemental fat and oil levels in high concentrate finishing rations are typically 2.0 to 6.0% of ration dry matter (DM). The principal inclusion determinant is considered to be the total dietary fat dry matter intake (DMI), taking into account the basal dietary fat levels and acknowledging the fat levels of all ration ingredients. Research has been unable to determine maximum or optimum tolerable total dietary fat levels although levels to 8.0% DM appear satisfactory. There is a decline in the marginal feeding value of supplemental fat as inclusion rates increase. Research has demonstrated fats and oils of animal and/or vegetable origin to be satisfactory.

Supplemental fat may interact with other ration ingredients or their nutrient properties. In particular it has been concluded when total dietary fat exceeds 5.0%, dietary calcium and magnesium should be not less than 0.9% and 0.3% respectively. In addition a diminished response to ionophores is indicated when

supplemental fat is fed in high concentrate diets. This suggests a cost saving opportunity by their exclusion when supplemental fat exceeds possibly 4.0% DM.

The judicious use of fats and oils when animals are either heat stressed during high environmental temperatures and humidity, or are experiencing reduced DMI due to a cold stress, can contribute to maintaining higher levels of animal performance.

A quality control program is necessary to monitor the product at delivery. Close attention should be paid to the fat and oil quality characteristics, and their maintenance during storage. Antioxidants need be added to all feed fats as appropriate to stabilise their condition, minimising the possibility of oxidation rancidity developing.

The storage, receival and delivery infrastructure to handle fats and oils needs to be robust, simple and adequate with prime consideration given to preserving product quality. Whilst incorporating specific design features, its manufacture and installation is basically simple.

There is no restriction on the use of animal fat in Australian stockfeeds.

1. INTRODUCTION

1.1 BACKGROUND

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The Meat Research Corporation's three-year Feedlot Consistency and Sustainability Key Program is aimed at increasing the profitability of the Australian cattle feedlot industry and developing cost-effective solutions to food safety, animal welfare and environmental imperatives within this sector of industry.

The program has identified a likely increase in the real cost of energy dense feedstuffs. Currently, feedgrains are the principal source of nutrient metabolisable energy [ME], and their [in]security of supply is seen as a core problem affecting the long-term prosperity of the Australian feedlot industry.

The cost of energy dense feedstuffs used by the feedlot industry will increasingly be determined by global feedgrain supply and demand interactions. It is possible that existing crops, new purpose-grown crops, or the improved and expanded use of existing energy dense by-products, could have the potential to assist the industry by providing competitively costed alternative or complementary feedstuffs with enhanced security of supply. In addition, the identification of new feedstuffs may enable the industry to expand or develop away from the current predominantly grain producing areas to new locations.

In Phase 1 of a three-phase research and development project, the Meat Research Corporation initiated three studies to examine:

_ alternative energy dense feedstuffs for the Australian cattle feedlot industry,

_ the expanded use of sugarcane by-products, and,

_ high ME silages.

Amongst the findings of the Phase 1 study was the conclusion that the use of fats and oils as a feedstuff was constrained by a general lack of appreciation of their worth. The existence of the relevant information was recognised, and a need identified for this to be collated and made readily available to local industry operators.

1.2 PROJECT DEFINITION AND OBJECTIVES

The Terms of Reference (Appendix 1) define the objectives of this Phase 2 study in the following way.

To compile and collate the information available on the use of fats and oils in cattle feedlot rations from test research and commercial experience in Australia and overseas, and present it in the form of a reference document for use by industry operators.

Feed grade fats and oils referred to here and examined in this study are readily available in three forms: oil seeds, commodity fats and oils and specialty fats (Refer 4.3).

The **oilseeds** are those oils derived from seeds, eg. cottonseed. They are high in fat (soybeans for example contain 18.0-24.0% oil) and as a source of ration supplemental fat are often available at a reasonable cost. They may therefore be valuable feedstuffs.

The **commodity fats and oils** include animal fats such as tallow or yellow grease and blends of animal and vegetable fats and oils. The cost of these fats and oils varies greatly in relation to grade and location.

The **specialty fats** refer to fats treated to make them more ruminally inert. Treatments include forming fine particles of solid fatty acids, encapsulation, or the formation of calcium soaps. These treatments are expensive, but they do form products that are claimed to be capable of feeding at higher levels than can be attained when feeding oilseeds, and commodity fats and oils. In addition, they can be used when the limits for these generally more reasonably costed feedstuffs have been reached.

2. COMMODITY FATS AND OILS IN AUSTRALIA

2.1 OVERVIEW

The term **fat** is frequently used in a general sense to include both fats and oils, or a mixture of the two. Fats and oils have similar general structure and chemical properties, but differing physical characteristics. Most fats are solid at ordinary room temperatures, while oils have lower melting points and are liquid at these temperatures.

It is estimated that 120 different countries in the world produce and consume fats and oils. World production is estimated for 1995/96 to have been 96 million tonnes (Backlong 1995) sourced principally from tree crops, annual plant crops, and the livestock industries.

Fats and oils fall into five main categories.

1. **Normal liquids** eg. soybean, rapeseed, sunflower oils. These constitute the most dominant category accounting for 42.0% of world production, of which 95.0% is used in foods. These are the market price setters.
1. **Premium liquids** eg. groundnut, cottonseed, maize, olive, sesame, sunflower oils.
1. **Palm and palm products** eg. palm oil. This is the fastest growing sector in supply terms, approaching 20% of world production.
1. **Laurics** eg. coconut, palm kernel oils. Approximately 60.0% of this category is used for technical purposes (eg. soap) and 40.0% for food.
1. **Animal fats** tallow and grease. These represent some 9.5% of world fats and oils production and are used in foods, the intensive livestock industries, pet food and soap manufacture.

Australia is a significant producer and exporter of the animal fats tallow and grease. Australian annual production of tallow and grease during the five years 1993-97 averaged 446,000 tonnes of which 322,000 tonnes (72.0%) was exported (USDA 1997). Australian production is forecast to be 387,000 tonnes in 1998 (down from 427,000 tonnes in 1997) behind only the United States (3,426,000 tonnes) and Brazil (458,000 tonnes). Exports are forecast to be 312,000 tonnes (81.0%) in 1998 (down from 340,000 tonnes, 80.0%, in 1997) second only to the United States (800,000 tonnes) (USDA 1997).
Total Australian exports of tallow and grease in 1994/95 amounted to 297,486 tonnes. Destinations were determined by Blacklog (1995) as follows.

China	73,528 tonnes	24.7%
South Africa	60,046 tonnes	20.2%
Pakistan	59,675 tonnes	20.1%
Taiwan	26,222 tonnes	8.8%
Bangladesh	22,888 tonnes	7.7%
Other	55,127 tonnes	18.5%

These exports were sourced from:

Queensland	160,976 tonnes	54.1%
Victoria	68,141 tonnes	22.9%
Western Australia	23,542 tonnes	7.9%
South Australia	20,794 tonnes	7.0%
Tasmania	12,506 tonnes	4.2%
New South Wales	11,455 tonnes	3.9%
Northern Territory	72 tonnes	-

While it is difficult to define precisely the production and destination of component Australian fats and oils, an overall approximation of the annual destination has been constructed from reported findings (O'Brien 1993; MRC 1996; Tapp 1996b) and from industry and trade sources (personal communication). It is presented in Table 2.1.

TABLE 2.1 Approximate annual destination of Australian fats and oils (tonnes)

Rendering End Product Tallow and Grease:					
1 Inedible	1.1 Export			325,000	
	1.2 Domestic				
		Soap and oleo chemicals	45,000		
		Intensive livestock	80,000		
		Pet food	12,000	137,000	462,000
2 Edible	2.1 Export			8,000	
	2.2 Domestic Food			70,000	78,000
Total Rendered End Product: 540,000		Tallow and Grease:			
Recycled and Residue Fats and Oils					
1 Food Industry Disposal	1.2 Export			5,000	
	1.2 Domestic				
		Intensive livestock	10,000		
		Manufacturing industry	10,000	20,000	25,000
2 Refinery Residual (Acid Oil)	2.1 Domestic				
		Intensive livestock	4,000		
		Manufacturing industry	1,000	5,000	5,000
3 Greasetrap Collection	3.1 Domestic				
		Manufacturing industry	5,000	5,000	5,000
Total Recycled and Residue Fats and Oils:					35,000
TOTAL FATS AND OILS **575,000**					

Source: Based on O'Brien 1993; MRC 1996; Tapp 1996a, 1996b; Industry and trade sources

Tallow is an end product of the rendering process. Its quality is largely determined by: the animal carcase fat and species; the ratio of abattoir material to boning material; the inclusion of other solid wastes, and solids recovered. The beef industry contributes approximately 70.0% of total tallow produced in Australia (Tapp 1996a).

The Australian rendered end product approximates 540,000 tonnes annually of which 207,000 tonnes (inedible 137,000 tonnes; edible 70,000 tonnes) are used domestically. In turn some 25,000 tonnes of the 45,00 inedible tonnes used for soap and oleo chemicals, and some 25,000 tonnes of the 70,000 edible tonnes used for domestic food, are exported in a value added form.

Whilst in the USA 60.0% of total inedible tallow production is used domestically in the livestock stock feed area, in Australia it is 16.0% (MRC 1995; industry sources).

In addition to renderings, there are recycled and residual fats and oils, totalling some 30-35,000 tonnes annually. These comprise an estimated wholesale and retail food industry disposal of 20-25,000 tonnes, refinery (eg. oilseed) residue or 'acid oil' of 5,000 tonnes, and grease trap collection of 5,000 tonnes (personal communication, industry sources).

Most recycled and residual fats and oils are consumed domestically in the intensive livestock and manufacturing industries, with limited quantities exported. The greasetrap collection product is considered low grade, and is decisively avoided by the intensive livestock industries.

In all, the Australian intensive livestock industries are estimated to consume annually some 80,000 tonnes of rendered inedible tallow and grease, and 14,000 tonnes of recycled and residue fats and oils. Of this, the cattle feedlot industry uses 20,000 and 14,000 tonnes respectively, together with a small quantity of vegetable oils in blends.

The livestock industry feed fats and oils are commonly based on:

- Animal Fats and Oils
  - Beef Industry Source
  - Pork Industry Source
  - Poultry Industry Source
- Blended Animal Fats and Oils
  - Blends of the above and possibly recycled food industry disposal fats and oils
- Vegetable Fats and Oil
  - Vegetable oils
  - Acidulated soap stocks
  - Other refinery by-products
- Blended Animal and Vegetable Fats and Oils

2.2 COMPOSITION, QUALITY CHARACTERISTICS AND FEEDING VALUES

As a consequence of the variety and abundance of fatty acids which may bind with glycerol, there are numerous triglycerides and their component fatty acids. The typical component fatty acid composition and chemical characteristics of some natural fats and oils are illustrated here (Table 2.2). An overview of fats and other lipids and fatty acids (characteristics, classification, properties) is appended (Appendix 2).

TABLE 2.2 Typical main component fatty acid composition and chemical characteristics of some natural fats and oils

	CAPRYLIC	CAPRIC	LAURIC	MYRISTIC	PALMITIC	PALMITOLEIC	STEARIC	OLEIC	LINOLEIC	LINOLENIC	SATURATED	MONOUNSATURATED	POLYUNSATURATED	IODINE VALUE	SAPONIFICATION VALUE
Carbon Atoms	8	10	12	14	16	16	18	18	18	18	18	20-24	18		
Double Bonds	0	0	0	0	0	1	0	1	2	3	0	1-6	2		
Animals Fats:															
Beef				3.8	26	3.8	15	42	0.1		45	55	0.6	48	198
Mutton				3	22	2.8	30	32	0.2		55	45	0.7	40	198
Pork			0.5	2	26	4	14	43	9	0.3	44	56.5	9.5	65	196
Vegetable Oils:					4		2	62	18	11		1.5		114	190
Canola	8	7	48	16	8	1	4	6	2			(6)		9	255
Coconut					12		2	26	59	1			60	125	190
Corn (Maize)				1	22	1	2	20	54				54	108	192
Cottonseed					6		4	18	19	53			72 (4)	180	190
Linseed				1	17	1	2	65	14					80	190
Olive				1	47		4	38	10					52	200
Palm	2	2	51	18	8		1	16	1					20	250
Palm Kernel					10		3	60	22		5			100	190
Peanut					17		2	39	39	3	(3)		42	87	190
Rice Bran					7		3	12	78		19		78	145	190
Safflower					9		5	45	41					110	190
Sesame					10		3	24	55	8			63	130	190
Soybean					6		2	26	66				66	135	190
Sunflower															

Source: Gardener Smith Pty Ltd, Milsons Point, NSW; Ensminger *et al* 1990.

The majority of fats comprise three fatty acid molecules combined with a glycerol molecule (triglyceride). The fatty acids give the respective fats their individual characteristics.

The feed fats have frequently inherited some myths associated with the terminology and specifications developed for their traditional primary uses. These specifications better define their quality and relevance to the soap and chemical industries than to the intensive livestock industries. For example, specifications commonly place an emphasis on titre (a measure of hardness), free fatty acid (FFA) content, and colour. For soap manufacture, high titre (harder) fats make harder soaps and lower titre (softer) fats make softer soaps. Likewise, a higher FFA content indicates a greater glycerine loss during manufacture, and a dark colour makes lower quality soaps. These terms have meaning, but they have little relevance in describing the nutritional qualities of fats and oils.

The characteristics of fats and oils which contribute to their nutritional quality, feeding value and acceptability can generally be described in terms of three criteria.

1. Purity,
1. Saturation, and
1. Stability.

Hardness is occasionally referred to as a guide to the ease with which the material might be handled.

The principal available indicators for these quality characteristics are:

- MIU (moisture, insoluble impurities, unsaponifiables)
- TFA (total fatty acids)
- FFA (free fatty acids)
- IV (iodine value)
- PV (peroxide value).

Purity

The purity of the fat is reflected by the impurities present, and its composition. It is a factor of MIU, TFA and FFA.

MIU (moisture, insoluble impurities, unsaponifiables) measures the gross contamination by non-fatty matter which has virtually nil feed value, and which affects the purity of a feed fat. The composite MIU of feedgrade fats should be less than 1.5%.

Moisture. Some condensation moisture is unavoidable with any feeding fat. However, moisture contributes neither energy nor any other benefit to the feeding value of fat and should be kept to a minimum. More significantly, moisture is detrimental in accelerating autocatalytic (non-enzymatic) oxidative rancidity due to corrosion of fat handling equipment. Moisture in the presence of high FFA and high temperature also promotes autocatalytic hydrolysis of the glycerides leading to a deterioration of the fat, and, subsequent glycerine loss in storage. Moisture has the added disadvantage of accumulating in the lower strata of fat storage units, making sampling difficult.

Insoluble impurities. These are usually small filterable particles of fibre, hair, hide, bone, soil, minerals or polyethylene insoluble in kerosene or petroleum ether. They tend to settle out accumulating as sludge in storages, and potentially clogging lines, valves and nozzles. Whilst these components do not necessarily represent hazardous contaminants, they contribute no energy or other beneficial value to the feeding value of fat.

Unsaponifiables. This is material which is soluble in petroleum ether but which does not react with sodium or potassium hydroxide to form soap (sterols, hydrocarbons, pigments, fat soluble vitamins, fatty alcohols and esters, waxes, mineral oils). It may include potential contaminant pesticides or other toxic chemicals. Certain problem compounds are contained in portions of the unsaponifiable, such as edema factor. Unsaponifiables contribute very little, if any, energy value to the feeding value of fat. Nevertheless, high unsaponifiable value is no more indicative of an animal health safety hazard than a low value is indicative of wholesomness.

The **Total Fatty Acids** (TFA) indicate the fat composition and hence purity of the feed fat source. Most supplemental fats will contain between 85.0% and 92.0% TFA.

> **TFA** comprise both those fatty acids combined with glycerol (intact glycerides) and the free fatty acids (FFA). Fat is composed of approximately 90.0% fatty acids and 10.0% glycerol. Fatty acids contain about 9.40 calories per gram, compared with 4.32 calories per gram for glycerol. Since fatty acids contain over twice the energy of glycerol and are the primary energy source in feeding fats, the TFA content acts as one indicator of energy content. Fatty acid levels less than 90.0% reflect dilutions with other ingredients and indicate that on the basis of TFA content the value of the fat product should be discounted (Zinn 1989a).
>
> **FFA** are those fatty acids in free form not linked to glycerol by an ester linkage. The oxidation of fat produces FFA as a by-product. In 'whole' fats, the presence of high FFA levels may indicate improper fat storage and/or handling. Hydrolysis may occur, as either enzymatic lipolysis during storage or prior to rendering, or as autocatalytic hydrolysis. The latter is often associated with oxidative rancidity.
>
> Rancidity is the oxidation (decomposition) primarily of unsaturated fatty acids resulting in disagreeable flavours and odours in fats and oils. The process occurs slowly and spontaneously, and may be accelerated by light, heat, and certain minerals. Rancidity may be prevented through proper storage and/or the addition of antioxidants.
>
> Antioxidants should be added to all feed fats to prevent rancidity occurring, particularly in the presence of high FFA levels.
>
> It has been concluded that FFA levels *per se* have little influence on the feeding value of fat for feedlot cattle (Zinn 1989a, 1989b, 1996).

Saturation

Saturation is indicated by the **iodine value** (IV) which denotes the degree of unsaturation of a fat or fatty acid. The higher the IV the more unsaturated and softer the fat.

Saturation provides a guide as to the fat’s origin. Feed fats with high IV values (>60) typically contain vegetable soapstocks, and those with lower IV values, are characteristically of animal origin.

Stability

Fat stability refers to the current state of oxidative rancidity as indicated by peroxide value (PV).

The PV of a properly handled fat should be equal to or less than 10. If less than five, the sample is currently not rancid. Fat rancidity can however change quickly depending on conditions. Smell might simply be its best practical indicator.

The presence of trace amounts of copper in complete mixed diets can greatly accelerate rancidity, particularly if the fat source has a high IV.

Hardness may be measured by **Titre** (°C) in addition to IV. For animal fats a titre over 40° denotes tallow, and under 40° grease.

2.3 PRODUCT DESCRIPTIONS AND SPECIFICATIONS

The specifications traditionally applied to fats and oils to determine grade and value, place the emphasis on titre (hardness), iodine value (saturation), free fatty acid content (composition), and colour. These are limited parameters when describing their nutritional value. Similarly limited are the terms edible and inedible where they apply to food usage rather than the feeding value of fats and oils.

Be this as it may, the bases for trading fats and oils in Australia are the American Fats and Oils Association Standards (AFOA Standards), export and domestic grades which rely on these parameters (Table 2.3).

TABLE 2.3 Standard grades, specification and quality tolerances for tallows and greases (NACMA 1996)

	Grade	Specifications				
		Titre[1] min	FFA[2] max	FAC[3] max	R&B[4] max	MIU[5]
1.	Edible Tallow	41.0	0.75	3	none	*
2.	Lard (Edible)	38.0	0.50	**	none	*
3.	Top White Tallow	41.0	2.00	5	0.5	1
4.	All Beef Packer Tallow	42.0	2.00	none	0.5	1
5.	Extra Fancy Tallow	41.0	3.00	5	none	1
6.	Fancy Tallow	40.5	4.00	7	none	1
7.	Bleachable Fancy Tallow	40.5	4.00	none	1.5	1
8.	Prime Tallow	40.5	6.00	13-11B	none	1
9.	Special Tallow	40.0	10.00	21	none	1
10	No 2 Tallow	40.0	35.00	none	none	2
11.	'A' Tallow	39.0	15.00	39	none	2
12.	Choice White Grease	36.0	4.00	13-11B	none	1
13.	Yellow Grease	***	15.00	39	none	2

1 Titre: °C
2 FFA: Percentage Oleic Acid
3 FAC: Fat Analysis Committee Colour Standards
4 R&B: Colour after Refining and Bleaching
5 MIU: Percent Non Fatty Matter Present

* Moisture maximum 0.20%. Insoluble Impurities maximum 0.05%.
** Lovibond Colour 5_T inch cell – Max 1.5 Red. Lard Peroxide Value 4.0 Milli Equivalent per Kilo Max.
*** Titre minimum, when required, to be negotiated between buyer and seller on a contract by contract basis.

Source: NACMA (1996)

Blending

Renderers and/or traders commonly blend animal fats and oils to individual market and/or customer requirements. They may incorporate vegetable fats and oils. The recycled fats and oils from the food industry for example, are frequently composite blends of plant and animal fats and oils. Blending is also practised to ensure ongoing consistency in product stability and composition. Individual renderers commonly apply brand specific specifications and descriptions to their own individual products and grades

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Specialised products have been developed for the feedlot industry. The specifications of two such products are illustrated in Table 2.4.

TABLE 2.4 Specification example of blended ruminant energy supplements based on selected fats and oils*

Specification	'Bulk Lot Fat'	'Bonlipid-2'**
Melting point range	38°C maximum	10°C maximum
Free fatty acids	55.0% maximum	35.0% maximum
Moisture and impurities	1.0% maximum	1.0% maximum
Pesticide residues	Within standard MRLs	Within standard MRLs
Fatty acid composition	Major fatty acids present: palmitic, stearic, oleic, linoleic	Major fatty acids present: palmitic, stearic, oleic, linoleic
Metabolisable energy	Up to 34MJ/kg	39MJ/kg

* Product information by courtesy Gardner Smith Pty Ltd, Milsons Point, NSW
** A "liquid vegetable oil based energy supplement for ruminants".

The National Agricultural Commodities Marketing Association (NACMA) specified basic properties for trading a number of fats and oils in Australia are appended (Appendix 4). These include refinery residue (acid oil) and the vegetable oils (soybean, sunflower, safflower, cottonseed, canola).

2.4 COST FACTORS

The cost of fats and oils for the domestic intensive livestock industries relate largely to the international tallow and vegetable oil markets. The domestic cost of feedgrade fats and oils is commonly quite volatile. It fluctuates widely in accordance with short and long term market supply/demand situations; increasing substitutions between products and sources; health trends, and exchange rates (MRC 1993; Figure 2.1). The Australian tallow producers are basically price takers.

FIGURE 2.1 Tallow cost trends (ex works Brisbane)
Source: MLA, Sydney

Some suppliers of feedgrade tallow attempt to even out the fluctuations. They seek to offer improved consistency of product cost to Australian end users over an extended period (Figure 2.2).

FIGURE 2.2 Feedlot grade tallow cost (ex works Brisbane)

Source: Gardner Smith Pty Ltd, Milsons Point, NSW

3. REVIEW OF COMMODITY FATS AND OILS IN CATTLE FEEDLOT FEEDING REGIMES

3.1 GENERAL

Fats and oils are the most energy dense feedstuffs. Their chemical and physical properties can enhance ration quality and livestock performance in the intensive livestock industries, where all major species have greatly increased their use in recent years.

Supplemental fats are commonly used in the USA cattle feedlot industry, particularly in south east and south west USA. Similarly, their use has been commonplace in major sectors of the Australian feedlot industry since the early 1970s.

Fats and oils are included in high concentrate feedlot finishing rations at typically 2.0 - 6.0% of ration DM. They increase diet energy and cattle energy intake to enhance average daily gains, improve feed use efficiency and/or improve carcase characteristics (Brethour *et al*, 1986; Zinn 1989a; Brandt and Anderson 1990; Krehbiel *et al* 1995a). Table 3.1 illustrates the impact replacing molasses with supplementary fat in feedlot diets containing 80.0% flaked milo. The results are increased daily gain, greater feed efficiency, and improved carcase characteristics in finishing beef cattle.

TABLE 3.1 Effects of 4.0% (3.5% DM) supplemental fat on finishing yearling steers

	Supplemental Fat Source			
	Control	**Soybean Oil**	**Tallow**	**Yellow Grease**[1]
Initial weight, kg	368.2	362.7	362.7	369.8
Final weight, kg	540.5	548.2	544.5	560.9
Daily gain, kg	1.42[e]	1.54[cd]	1.50[d]	1.59[c]
Daily feed, kg DM	8.90[cd]	8.91[cd]	8.67[c]	9.13[d]
Gain/feed	0.160[b]	0.173[a]	0.174[a]	0.175[a]
Dressing percentage	63.42[d]	64.57[c]	64.15[c]	64.13[c]

1 Yellow grease was blend of approximately 50.0% spent restaurant frying oils, and 50.0% tallow
a,b Means in a row with different superscripts differ (P<0.01).
c,d,e Means in a row with different superscripts differ (P<0.05).
Source: Brandt and Anderson (1990)

Similarly, Gramlich *et al* (1990) noted an increase in gain/feed when 4.0% tallow was added to a diet based on dry-rolled corn, and Cole and Hutcheson (1987) recorded improved average daily gain, dry matter intake and efficiency in two trials when adding 4.0% fat blend to the receiving diet of groups of stressed feeder calves averaging 195 and 173kg.

However, the optimal ration inclusion levels for maximal performance are influenced by a number of factors: total dietary fat intake; the interactions of fat with other ingredients; dietary nutrients, and/or the environment. Furthermore, the basic quality characteristics of commercially available fats and oils vary considerably. This variation can markedly influence diet intake and hence animal performance. It potentially confuses the comparable contribution various feed fats make to livestock production.

3.2 FAT UTILISATION BY FEEDLOT CATTLE

The utilisation of supplemental fats and oils in beef cattle diets is a dynamic function of:

- level of supplementation, basal dietary fat levels and source of fats;
- interaction with other ingredients and nutrients;
- interaction with the climatic environment;
- quality characteristics, and
- acceptability and/or palatability.

3.2.1 Supplemental Fat Level and Sources

In practice it is typically recommended that supplemental fat and oil levels in high concentrate finishing rations be at 2.0 to 6.0% of ration DM.

Zinn (1989a) reported that cattle fed on a steam-rolled barley based finishing diet supplemented with 0, 4.0 or 8.0% yellow grease or animal-vegetable fat blends, showed linear improvements in weight gain, feed conversion, and carcase characteristics (Table 3.2). These improvements were evident under the conditions of this trial for supplementation to as high as 8.0% of diet DM.

TABLE 3.2 Influence of level of fat supplementation on performance of feedlot steers

	Level of Fat Supplementation (DM)		
	0%	**4.0%**	**8.0%**
Empty body weight, kg			
Initial	306	304	304
Final[a]	404	412	426
Empty body gain			
Weight, kg/d[a]	0.83	0.92	1.02
Fat, kg/d[a]	0.265	0.313	0.399
Protein, kg/d[b]	0.126	0.135	0.141
Dry matter intake, kg/d	6.19	6.18	6.42
Empty body gain/intake[a]	0.133	0.147	0.159
Carcase weight, kg	274	280	291
Marbling score, degrees[bc]	4.09	4.21	4.35

a Linear effect, P<.01
b Linear effect, P<.10
c Coded: minimum slight = 4, minimum small = 5, etc
Source: Zinn (1989a)

There were no interactions between level of fat supplementation and fat type (animal, vegetable, blended). This data indicated that high levels of fats with varying fatty acid composition can be used in finishing beef diets.

Increasing amounts of supplemental fat may however depress both daily weight gain and dietary DM conversion. This has been reported for levels as low as 3.0%, but the negative responses that have occurred have been mostly when supplementary fat levels exceed 5.0% of dietary DM (Zinn 1992a, 1994).

Brandt (1992) observed that much of the inconsistency in growth performance response to supplemental fat may be more related to total dietary lipid intake rather than to percentage supplemental fat.

In review, Brandt (1995) noted the maximum feed efficiency response to supplementary fat occurred when supplemental fat constituted approximately 4.0 to 5.0% of the diet for yearling cattle. Increasingly higher diet inclusion levels typically depressed DM consumption, possibly to the extent that animal performance was eventually reduced.

Palmquist and Jenkins (1980) noted the intestinal digestibility of supplementary fat appears to remain rather constant up to about 4.0% of diet, averaging roughly 80.0%, and then declines. Above 4.0% supplemental fat (5.0-6.0% total dietary fat) true digestibility declines to about 56.0%. Zinn (1994) demonstrated more dramatic reductions in intestinal digestibility when the true digestibility of supplementary tallow soapstock at 8.0% and 12.0% DM levels averaged 63.0% and 40.0% respectively.

In review, Palmquist (1994) concluded that numerous factors may limit the amount of fat that can be fed to ruminants. The effects of high amounts of dietary fat on ruminal microbial metabolism, fatty acid absorption, oxidation and feed uptake, limit its incorporation in ruminant diets to 16.0-20.0% of ME. Nevertheless, this is a significant increase over the 6.0-10.0% of ME provided by fat in unsupplemented diets, and provides the opportunity to increase the energy efficiency and flexibility of feeding management of highly productive ruminants.

Zinn (1994) in examining the effects of excessive supplemental fat on feedlot cattle concluded the total lipid DM intake was a better predictor of post ruminal lipid digestibility than percentage supplemental fat, and that the optimal growth performance response to supplemental fat is obtained when total lipid intake levels are less than 1.6g/kg body weight. The detrimental effects of excessive supplemental fat are primarily associated with depressed intestinal lipid digestibility, and characterised by

- decreasing DMI in excess of normal expected substitution rates,
- mediocre or depressed daily weight gain and dietary DM conversion, even after supplementary fat is removed from diet.

Australian industry experience confirms these observations of the effects of excessive dietary fat. Acute drought affected yearlings were fed a carefully processed grain and high oilseed based concentrate diet containing 5.0% supplemental fat. The diet, while apparently designed to be balanced and adequate with 1.1% calcium, five times vitamin A requirements (with cattle also receiving a massive vitamin A treatment on entry), and more than adequate protein, had an estimated 12.0% dietary fat level. After an apparently satisfactory introductory period, a significant number of stock decreased their DMI, thereby decreasing production efficiency with many showing signs of vitamin A deficiency. There was widespread animal malaise associated in part with an increased incidence of viral disease. The majority of affected animals failed to respond fully to remedial treatment and remained as poor performers in the feedlot after ration adjustments, or when removed to quality irrigated pastures (personal communications, industry sources).

There are also reported instances in New Zealand and Australian feedlots where fats and oils sourced from the sheep industry have been found to excessively decrease apparent diet palatability and acceptablity (personal communication industry sources), thereby reducing DMI.

3.2.2 Fat Interactions

The possible interactions between supplemental fat and other ration ingredients, or their nutrient properties, have been examined in relation to animal production response.

Grains

The optimal level of supplemental fat feeding may relate to the type of cereal grains comprising the concentrate. Hale (1986) speculated that less supplemental fat may be desirable in diets containing corn which comprise 4.0% DM fat, than in diets containing other cereal grains such as barley, wheat, and sorghum which have relatively less fat (approximately 2.2%, 2.3%, 3.0% DM ether extract respectively [NRC 1996]). In general, results have been more positive when adding fat to barley- or wheat-based finishing diets than to corn-based diets (Brandt 1995).

However, results from an experiment specifically designed to evaluate the growth performance responses to 6.0% DM (0.45kg/day) supplemental yellow grease or cottonseed oil soapstock in steam-flaked corn and steam-flaked wheat-based finishing diets, indicated no interactions between grain type and supplemental fat type on steer growth (Zinn 1992a). It concluded the effects of primary grain type (corn v wheat) on the feeding value of supplemental fat when equal to or less than 6.0%, were of limited practical significance.

Subacute acidosis is a common problem in beef cattle during adapting to high grain finishing diets. It has been suggested that if supplemental fat reduces the rate of starch digestion in the rumen this may lead to more consistent intake patterns and reduce the risk of acidosis, bloat, and health problems associated with erratic feed consumption patterns (Huffman *et al* 1992). Following a series of trials to evaluate this aspect, Krehbiel *et al* (1995b) concluded that although the addition of fat to feedlot diets produces benefits by reducing diet fines and increasing the energy content of the diet, the addition of fat to dry rolled corn-based finishing diets does not reduce subacute acidosis.

White Cottonseed

White cottonseed is highly valued in feedlot and lactating dairy cow ration formulations as a source of nutrient energy, crude protein, NDF and ADF. It has an assigned energy value similar to that of steam-flaked corn (NRC 1996; Zinn 1996b), due primarily to its high fat (23.0% DM) content. When favourably costed, large amounts are fed to feedlot cattle in the USA, Mexico and Australia. Concurrently moderate to high levels (3.0-6.0% DM) of supplemental fat are also commonly used in diet formulations in these areas.

Zinn and Plascencia (1993) examined the interaction of white cottonseed and supplemental fat on the digestive function in cattle. Yellow grease (5.0% DM) and white cottonseed (20.0% DM) was substituted for steam-flaked corn in an 80.0% DM concentrate growing-finishing diet. It was concluded the feeding value of white cottonseed is diminished in growing-finishing diets containing moderate levels (5.0% DM) of supplemental fat. The basis for this does not seem to be related to depressed digestibility of fat, *per se*, but rather to a more general negative associative effect of high total dietary fat intake on ruminal and total tract digestibility of organic matter. Although reduced digestibility was offset to some extent by decreased ruminal methane energy loss, ME content of white cottonseed was 20.0% lower when fed (at 20.0% DM) in combination with supplemental fat at 5.0% DM.

Roughage

Roughage is more expensive per unit of available energy than concentrates. Feedlots commonly move cattle to high concentrate, low roughage diets as soon as is practical, frequently including a fat supplement to further increase the energy density of the finishing diet. The effects of these high energy diets on gain efficiency are well documented.

The effects of forage level on the comparative feeding value of supplemental fat in growing-finishing diets for feedlot cattle on their growth-performance and digestive function have been evaluated. Zinn and Plascencia (1996) concluded the supplementation of a (medium forage) 30.0% DM forage (alfalfa hay) finishing diet with 6.0% DM yellow grease will permit growth-performance similar to that of steers fed a 10.0% DM forage diet without supplemental fat. The improved performance may be attributed to increased diet energy density, positive associated effects on protein flow to the small intestine and decreased ruminal methane production.

In high forage diets (ie. approximately 69.0% chopped wheat straw as fed) Moore *et al* (1986) found low level (2.0 or 4.0% as fed) additions of fat tended to stimulate the DM intake of steers (325kg) without adversely affecting diet digestibility. However, when fat additions were greater than 4.0%, even in the form of white cottonseed, fibre digestion was decreased and the advantages attributable to added fat declined. Fat absorption appeared to decline sharply when lipid intake exceeded 600g/day. They concluded attempts to increase caloric density of low quality roughage diets by fat additions greater than 4.0% may be counter productive.

Method of Fat Supplementation

The feeding value of fat has been examined in relation to the method of supplementation (Zinn 1986). Three methods of fat supplementation were compared namely when the fat portion of the diet was:

- added directly to the grain prior to adding other ration ingredients;
- added directly to the hay prior to adding other ration ingredients, and
- applied as the last step in the batch mixing.

for each of three levels (3.0, 6.0 and 9.0%) of fat supplementation.

All three alternative methods gave similar results when the level of fat supplementation was less than 6.0%. At the 9.0% level of supplementation, adding fat directly to the hay resulted in marked reductions in gain and efficiency.

As supplemental fat is usually added at less than 6.0%, the practical conclusion is that it matters little (from a nutritional perspective) when the fat is added in the mixing cycle.

Similarly, Zinn *et al* (1998b) examined the influence of adding 5.0% yellow grease to steam flaked corn grain prior to other ingredients, and adding 5.0% yellow grease next to the last step (prior to adding molasses). It was concluded the method of fat supplementation does not influence the feeding value of fat for feedlot cattle.

Nitrogen

Optimal animal performance is dependent upon specific relationships between dietary nitrogen (protein) and energy concentration. Fat supplementation increases the energy density of feedlot diets, possibly requiring concurrent adjustment to ration protein levels for optimum animal performance.

When evaluating this theory however Carrica *et al* (1991) failed to detect an interaction between supplemental fat (0, 4.0% DM) and protein level (11.8, 12.8, 13.8% DM) in young steers (290kg entry weight) fed for 168 days. This was possibly because:

- fat increased the diet energy content by 5.0-7.0% which was less than enough to influence the protein: energy balance critical for the conditions applying, and/or
- fat increased the efficiency of microbial protein synthesis (Zinn, 1989b; Jenkins and Fotouhi, 1990) and apparent nitrogen digestibility.

Urea is a widely used source of supplemental nitrogen in ruminant rations, and has been shown to be a satisfactory source of NPN in fat supplemented diets (Zinn 1988, 1989a). In a 149 day feeding trial, fat supplementation (6.0% DM yellow grease) of a steam-flaked corn-based finishing diet improved ration efficiency (9.9%) and ration net energy (10.3%). Substituting soybean meal (on an equal supplemental N basis) for urea (1.0% DM) linearly depressed the net energy value of the diet. It was concluded that substituting soybean meal for urea as a source of supplemental N in a steam-flaked corn-based diet may not improve the feeding value of the supplemental fat (Zinn 1989c).

A primary factor limiting the feeding value of fat at higher levels of supplementation is its decreasing rate of small intestinal digestibility. Zinn (1992b) postulated that by simultaneously increasing the level of protein reaching the small intestine, the digestibility of fat might also be enhanced. He refers to unpublished data recording a 123 day 68 head trial where fat supplementation (5.0% DM yellow grease) improved efficiency (8.6%) and net energy of the diet (9.6%). The addition of a 2.0% high-bypass protein did not however further influence feedlot performance. In a later trial the addition of a 2.0% high-bypass protein supplement did not influence the intestinal digestibility of fat in the fat supplemented diet.

Minerals

Calcium and its possible interaction with fat in ruminal diets has possibly received most attention of the macro elements.

It is commonly advocated that the calcium content of ruminal diets containing high fat be increased with the presumption that calcium reacts with fatty acids in the rumen to remove their inhibitory effects. Supporting research has however been inconsistent.

Bock *et al* (1991) examined 0.6 and 0.9% DM dietary calcium levels in a high (80.0% DM) wheat-based concentrate finishing diet fed to steers containing 3.5% DM tallow or soybean oil soapstock, and observed an interaction between calcium level and fat source. With soybean oil soapstock, increasing the calcium level increased ADG (5.0%), with little difference in feed conversion. In contrast, with supplemental tallow, increasing the calcium level decreased ADG (9.0%) and feed efficiency (6.0%).

Zinn and Shen (1996) compared 0.45 vs 0.90% DM dietary calcium levels in a barley-based finishing diet containing 0 vs 5.0% DM yellow grease. There was no interaction between dietary calcium and the feeding value of supplemental fat. However, total lipid intake in that trial was not extreme (6.8% of diet DM). In a further trial Zinn *et al* (1998c) evaluated the effect of 0.5, 0.7 and 0.9% DM dietary calcium in a high supplemental fat (6.0% DM) corn-based finishing diet (11.1% DM total lipid) on growth performance. They found increasing dietary calcium levels improved daily gain and feed efficiency. Most of the improvement came when dietary calcium level was increased from 0.7 to 0.9%. NEm and NEg values of the diet were increased by 6.5 and 8.0% respectively, and dressing percentage and rib eye area improved. It was concluded dietary calcium levels greater than 0.7% DM are necessary to achieve optimal performance in feedlot steers fed a high fat finishing diet.

Palmquist (1992) reviewed the use of fat in dairy cattle rations. He concludes that in feeding guidelines for maximising the use of fat in dairy rations, while fatty acid digestibility is greater than 80.0% at low fatty acid intake, it declines as intake exceeds 4.0 - 5.0%. Unabsorbed fatty acid combines with calcium and magnesium in the lower intestine, decreasing digestibility of these essential minerals. He recommends that in fat supplemented diets, dietary calcium and magnesium content be kept at minimum 0.9 and 0.3% DM respectively. This is supported by Emery and Herdt (1991) who suggest 1.0% and 0.35% DM respectively. These authors suggest supplemental fatty acids decrease calcium absorption by 25.0 to 40.0%, and magnesium absorption by perhaps 15.0%.

Ionophores

Supplemental fat and ionophores are often used concurrently in beef finishing diets and may influence rumen fermentation similarly. Interactions between fat and ionophores have frequently been noted in studies when lasalocid or monensin has been included in the diet (Brethour 1984; Brandt *et al* 1988, 1991; Brandt and Pope 1992), although not by Zinn (1988). Clary *et al* (1993) examined the effect of supplemental fat and ionophores in finishing diets on feedlot performance. Their results indicated a diminished response to ionophores when supplemental fat (4.0% DM) is fed in high-concentrate, beef cattle diets. Ionophores did not significantly improve efficiency or ADG when included in a fat supplemented (4.0% DM) diet feed for 116 days. Similar results were reported by Brethour (1984), who noted improvements in efficiency and ADG when lasalocid or a commercial fat blend were fed separately, but not when they were fed in combination. Clary *et al* (1993) suggested the effect may be in part a result of the negative associative effects between these additives on the end products of ruminal fermentation.

Zinn and Borques (1993) also concluded that the growth performance responses to supplemental monensin may be small in fat-supplemented (4.0% DM) high energy finishing diets for steers. These authors speculated that monensin may be rendered inactive when fed with fat because it is fat soluble.

Fat Soluble Vitamins

It has been speculated fat supplementation may interact with the digestion, absorption, or metabolism of fat soluble vitamins (Brandt 1995). The consequence of this has however been generally discounted as most feedlot operators commonly add vitamin A and E to rations at levels several times the NRC (1996) recommendations. Brandt records that no symptoms of fat soluble vitamin deficiency have been observed in any of their research with supplemental fat.

It is suggested however, when cattle are fed for exceptionally long periods (180 days plus) care be taken to ensure actual vitamin A and E diet levels are comfortably adequate.

3.2.3 Fat and the Climatic Environment

Fat supplementation appears beneficial when environmental temperature and humidity are high and animals are heat stressed.

The digestion and metabolism of feed nutrients causes metabolic heat production. Beef cattle typically respond to high temperature thermal stress by reducing DMI. They thereby reduce the metabolic heat load and energy expenditures associated with dissipating heat, with resultant reductions in animal performance.

The addition of fat increases the energy concentration of the diet to compensate for the reduced intake. It may also lower heat production and thus reduce the amount of heat the animal, already in a heat-burdened state, must dissipate. Additionally, increased dietary fat intake effectively reduces nitrogen loss in cattle exposed to high environmental temperatures (O'Kelley 1986). The end result is the maintenance of higher levels of animal performance during periods of heat stress.

In cold environments, the extra heat increment associated with the digestion of non-fat containing diets, contributes to keeping the animals warm and may not constitute an energy loss. On the other hand, should there be a cold stress related reduced DMI, the addition of fat again increases the energy concentration of the reduced diet to compensate for the reduced intake, and so contributes to production.

Overall, there appears to be a literature void in the area of fat and the climatic environment for the ruminant species, particularly finishing cattle (Brandt 1995).

3.2.4 Supplemental Fat, Carcase Composition and Meat Quality

Supplemental fat appears to have an impact on carcase composition in a manner independent of liveweight and liveweight gain.

In review, Doreau and Chilliard (1997) concluded fat supplementation in ruminant diets leads to an increase in the proportion of fat in carcases whatever the nature of the dietary lipids; the weight of all adipose tissue is increased but not the proportion of fat in muscles.

Zinn and Plascencia (1996) found supplemental fat (6.0% DM) significantly increased marbling score, sufficient to move the average carcase a full grade from high Select to low Choice, and tended to increase the percentage of kidney, pelvic and heart (KPH) fat. This is in common with previous studies which discovered fat supplementation increased marbling score (Zinn 1989a; Brandt and Anderson 1990), increased percentage KPH (Zinn 1988, 1989a, 1992a; White *et al* 1992; Clary *et al* 1993) and fat thickness (Zinn 1988, 1989a, 1992a; Boucqué *et al* 1990; Huffman *et al* 1992).

The effect of supplemental fat on longissimus muscle area is unclear.

Zinn and Placencia (1996) observed differential effects of supplemental fat on longissimus muscle area, fat thickness, and percentage retail yield, depending on dietary forage level. Adding fat (6.0% DM) to the low-forage (10.0% DM alfalfa) diet decreased longissimus muscle area and retail yield, whereas adding fat to the high-forage (30.0% DM alfalfa) diet increased longissimus muscle area but did not affect retail yield. Earlier, Zinn had observed a 4.0% DM fat supplement was associated with an increased longissimus muscle area in a trial conducted involving a 12.0% DM roughage ration (Zinn 1988). A 6.0% DM fat supplement was associated with an increased longissimus muscle area in a trial involving a 12.0% DM roughage ration (Zinn 1992a).

Supplemental fat has been demonstrated to positively influence dressing percentage, albeit slightly, likely due in part to the increased KPH fat (Brandt *et al* 1988; Brandt and Anderson 1990; Zinn 1992a; Clary *et al* 1993; Zinn and Placencia 1996). Brand and Anderson (1990) noted that fat supplementation did not influence dressage percentage when the feeding period was less than 90 days.

Brandt *et al* (1992) reported 4.0% DM yellow grease fat supplement to have an additive adverse effect (slight) on fat colour, attributed to the pigments associated with the fat. However the supplemental fat improved lean meat colour.

Consistently, the incidence of liver abscess has not been affected by fat supplementation (Bock *et al* 1991; Huffman *et al* 1992; Clary *et al* 1993; Krehbiel *et al* 1995b; Zinn and Placencia 1996).

Fat supplementation generally does not modify tenderness or water retention of muscle (Clinquart *et al* 1995). The effect on flavour is variable and opposite results have been obtained with lipids from rapeseed, an improvement by Tesfa *et al* (1992) and a degradation by St John *et al* (1987).

3.3 FEEDING VALUE OF FATS AND OILS

3.3.1 Energy Value of Supplemental Fats and Oils

The National Research Council published nutrient composition of fats and oils (NRC 1996) are presented in Table 3.3.

TABLE 3.3 NRC composition of fats and oils (DM basis)

		Value as determined at Maintenance Intake				Net Energy Values for growing cattle				Crude	Ether
	DM	TDN	DE	ME		NEm		NEg		Protein	Extract
	%	%	Mcal/kg	Mcal/kg	*MJ/kg*	Mcal/kg	*MJ/kg*	Mcal/kg	*MJ/kg*	%	%
Fat, animal, hydrolysed	99.2	177	7.30	7.30	*30.54*	6.00	*25.10*	4.50	*18.83*	-	99.2
Oil, vegetable	99.8	177	7.80	6.40	*26.78*	4.75	*19.87*	3.51	*14.69*	-	99.9

Source: NRC 1996

Various research has determined a range of energy values for fats and oils, as a result of interactions between supplemental fat and other dietary ingredients, nutrients, or the climatic environment on cattle performance.

The NRC, for example, indicates lower NE values for fats of vegetable origin. Blended fats comprising 30.0% tallow with fats of vegetable origin have however been shown to increase the energy value of the blend to that of tallow. Brandt (1995) concludes that if the basic quality of the blend is good, blended animal-vegetable fats are equivalent to animal fats in energy value for feedlot cattle.

Total dietary fat will influence the energy value of supplemental fat (refer 3.2.1). Zinn *et al* (1998a, personal communications) has developed software accounting for the decline in the marginal energy value of supplemental fat as inclusion rates increase. The values are influenced by type and size of animal, feeding regime, intake, basal dietary fat levels and the supplementary rates (Table 3.4) of which there are a vast range of combinations. The energy estimates recognise that fat is not metabolised in the rumen, and there is no heat of fermentation, nor loss of methane.

TABLE 3.4 Feeding value of supplemental fat illustrated for differing animal weights and basal dietary fat levels (DM basis)

Animal Weight kg	Basal Dietary Fat %	Supple-mental Fat %	Total Dietary Fat %	ME MJ/kg	NEm MJ/kg	NEg MJ/kg	Relative Value
350.0	1.0	1.0	2.0	33.05	27.15	22.10	1.082
		2.0	3.0	32.46	26.61	21.63	1.060
		3.0	4.0	31.77	25.99	21.07	1.035
		4.0	5.0	30.95	25.25	20.43	1.006
		5.0	6.0	29.98	24.36	19.65	0.970
		6.0	7.0	28.82	23.31	18.73	0.929
		7.0	8.0	27.46	22.07	17.64	0.879
		8.0	9.0	25.84	20.60	16.35	0.820
		9.0	10.0	23.95	18.88	14.84	0.752
		10.0	11.0	21.76	16.89	13.09	0.673
	4.0	1.0	5.0	28.64	23.14	18.58	0.922
		2.0	6.0	27.44	22.05	17.63	0.879
		3.0	7.0	26.04	20.78	16.51	0.828
		4.0	8.0	24.39	19.28	15.19	0.768
		5.0	9.0	22.47	17.53	13.66	0.698
		6.0	10.0	20.25	15.51	11.89	0.618
		7.0	11.0	17.70	13.19	9.85	0.525
		8.0	12.0	14.79	10.54	7.53	0.420
		9.0	13.0	11.49	7.54	4.90	0.300
		10.0	14.0	7.77	4.16	1.93	0.166
550.0	1.0	1.0	2.0	33.21	27.30	22.23	1.088
		2.0	3.0	32.71	26.84	21.82	1.069
		3.0	4.0	32.13	26.32	21.36	1.048
		4.0	5.0	31.46	25.71	20.83	1.024
		5.0	6.0	30.69	25.00	20.21	0.996
		6.0	7.0	29.77	24.18	19.48	0.963
		7.0	8.0	28.71	23.20	18.64	0.924
		8.0	9.0	27.47	22.08	17.65	0.879
		9.0	10.0	26.03	20.77	16.50	0.827
		10.0	11.0	24.38	19.27	15.18	0.768
	4.0	1.0	5.0	29.56	23.99	19.32	0.955
		2.0	6.0	28.63	23.13	18.57	0.921
		3.0	7.0	27.54	22.14	17.70	0.882
		4.0	8.0	26.28	20.99	16.69	0.836
		5.0	9.0	24.82	19.67	15.53	0.783
		6.0	10.0	23.15	18.15	14.20	0.723
		7.0	11.0	21.24	16.41	12.67	0.654
		8.0	12.0	19.07	14.44	10.95	0.575
		9.0	13.0	16.62	12.21	9.00	0.487
		10.0	14.0	13.88	9.72	6.81	0.387

Source: Zinn *et al* (1998a)
ZAP 1.16 Visual Feedlot Consultant Registered Software 1997-98

Feeding values for marginal increases in supplemental fat levels are illustrated in Figures 3.1 and 3.2 for a 350kg live animal with basal dietary fat levels of 1.0 and 4.0% respectively.

In Australia where the basic diet grains are most likely to be the relatively low fat grains, such as barley or wheat (refer 3.2.2), higher levels of supplemental fat should be practical in comparison to the USA where corn predominates.

FIGURE 3.1 Feeding value of supplemental fat, when basal dietary fat 1.0%, animal 350kg live (DM basis)

Source: Zinn *et al* (1998a)
ZAP 1.16 – Visual Feedlot Consultant Registered Software 1997-98

FIGURE 3.2 Feeding value of supplemental fat, when basal dietary fat 4.0%, animal 350kg live (DM basis)

Source: Zinn *et al* (1998)
ZAP 1.16 – Visual Feedlot Consultant Registered Software 1997-98

3.3.2 Quality Characteristics of Feed Fats and Oils

Much attention is directed towards the energy value of supplemental fats and oils, and the factors influencing their energy contribution to production diets. Additional factors affecting their contribution relate to diet acceptability and feed intake. These may form the basis for constraints on supplementation. The reasons for the occasional negative impact of supplemental fat on diet acceptability are frequently unclear. However, each time the problem arises attention is drawn to the importance of 'quality'.

The quality characteristics of fats contributing to their nutrient energy feeding value and acceptability can generally be described in terms of **purity** and composition**, saturation,** and **stability** as outlined previously (refer 2.2). Their principal available indicators are ...

- MIU (moisture, insoluble impurities, unsaponifiables)
- TFA (total fatty acids)
- FFA (free fatty acids)
- IV (iodine value)
- PV (peroxide value).

The significance of these indicators as regards the nutrient energy value of the fats and oils can be summarised as follows:

MIU – Moisture, insoluble impurities, unsaponifiables have virtually nil feed value, and their occurrence reduces the feed's nutrient energy value. The maximum acceptable should be 1.5%, above which discounts are valid.

TFA – Total fatty acid content acts as one indicator of feed nutrient energy value. A TFA less than 90.0% reflects dilutions with other ingredients so lowering energy values, and warranting a purchase cost discount.

FFA – It has been concluded free fatty acids levels *per se* have little influence on the feeding value of fat for feedlot cattle (Zinn 1989a, 1989b, 1989c).

IV – Iodine value denotes the degree of unsaturation of a fat or fatty acid, and a guide as to its origin.

The potential influence the unsaturated:saturated fatty acid ratio might have on the feeding value of supplemental fats has been controversial.

Early in vitro studies demonstrated unsaturated fatty acids play a more active role in inhibiting ruminal bacteria, particularly cellulolytics, with oleic (C18:1) the most inhibitory of the unsaturated fatty acids tested. The cellulolytics, however, play a lesser role in the digestive function of feedlot cattle and it has been concluded the effects of the unsaturated:saturated fatty acid ratio may be limited under feedlot conditions (Henderson 1973; Maczulak *et al* 1981).

While a number of researchers have frequently noted a depression in feedlot animal performance with yellow grease (higher degree of unsaturation) compared to tallow (lower degree of unsaturation), the results have been inconsistent and are inconclusive (Brandt 1988).

It is concluded, generally, growing-finishing trials with feedlot cattle have not revealed consistent differences between fats of animal or vegetable origin such as tallow, yellow grease, blended animal-vegetable soapstock, cottonseed soapstock or soybean soapstock when supplemental fats comprise less than 8.0% of diet DM (Zinn 1996a).

PV – Peroxide value, refers to the current state of oxidative rancidity, and is not indicative of nutrient energy values.

3.4 OTHER CONSIDERATIONS

Efficiency

In addition to the nutrient energy it can contribute to animal feeds, supplemental fat may also assist **efficiency** through its impact on dust control, palatability, lubrication and formula density.

Dust Control – The strategic use of a supplemental fat can reduce dust in feed processing and mixing areas, improving feed mill cleanliness and worker comfort. By removing dustiness and fines in a dry mixed ration, it also enhances appeal to animals.

Palatability – Fat can enhance feed palatability and acceptability directly and/or indirectly as a result of improved texture.

Lubrication – Through the lubrication of surfaces, fat can reduce friction and mechanical energy usage, so enhancing the life of feed mixing and handling equipment, and reducing energy costs.

Formula Density – Fat, as an energy dense source of energy can reduce the amount of product and amount of waste to move physically.

Storage Management

There is a **storage management responsibility** for the effective use of fats and oils as a nutrient energy source.

The quality of feed grade fat is sensitive to proper handling and storage in every aspect of its use requiring the producer, supplier, and customer to handle and store the product correctly and with care.

- Fat contact with yellow metals (valves and valve seats, piping, pipe connections, heating coils, atomisers) needs to be avoided. Yellow metals (brass, copper) will cause fat to oxidise and become rancid at a much increased rate.
- Fat should be stored at cool temperatures except at the add tank. High temperatures cause fat breakdown and rancidity.
- Fat storage tanks need to be cleaned on a regular basis. Sludge build-up in the bottom of the tank can cause increased rancidity, and requires frequent bleeding off.
- Fat should be moved and stored with minimal contact with both air and moisture. The more contact, the more likely the fat oxidation process will be sped up.

It is important that **antioxidants**, of which there are a number commercially available, be used to safeguard fat quality. For maximum effectiveness they should be added at source storage, and certainly not later than supplier point of dispatch. The supplier should confirm their correct inclusion.

Certification

There is also a responsibility for the fat supplier to **certify the contaminant quality** of his product. As with any feedstuff, fats and oils may become adulterated, and may bear poisonous or deleterious substances possibly injurious to health. The potential for feeding fats to become contaminated with pesticides or other toxic chemicals is, in common with other feedstuffs, real. The fat supplier has the responsibility to ensure his product is contaminant free, and should certify each shipment delivered to be free of pesticide and other toxic chemicals.

4. COMMODITY FATS AND OILS AND THE AUSTRALIAN CATTLE FEEDLOT INDUSTRY

4.1 FATS AND OILS SWOT ASSESSMENT SUMMARY

Strengths

- Constitutes the most energy dense feedstuff.
- Acts as suitable energy supplement for cattle feedlot diets.
- Frequently offers a satisfactorily costed source of ME.
- Permits greater dietary energy density.
- Has the ability to enhance palatability, improve ration structure, reduce fines and control dustiness in feed.
- Suppresses dust in workplace.
- Lubricates feed processing equipment.
- Is available in consistent supplies.
- Is easy to use once infrastructure is established.

Weaknesses

- Acts as a source of nutrient energy only.
- Requires attention to adequacy of dietary protein and vitamin A levels at higher supplementation levels.
- Has optimum upper level supplemental inclusion rates probably in order of 5.0-6.0%, relative to total dietary fat levels, and, interactions.
- May reduce digestion in small intestine and absorption of calcium and magnesium, necessitating their supplementation at higher dietary fat levels.
- May, in excessive supplemental levels, depress DMI in association with reduced rumen function.
- May vary in quality, requiring close monitoring.
- Entails risk of adverse palatability effect (as result of quality reactions).
- Contains risk of impurities, contaminants, and toxins which necessitate close monitoring.
- Requires attention to handling to avoid rancidity.
- Is subject to product cost fluctuations.
- Requires specific purpose designed infrastructure.
- Is less acceptable/palatable if based on sheep industry source.

Opportunities

- Offers energy dense feedstuff, frequently at favourable ME cost.
- Livestock rations typically contain relatively small amounts of basal dietary fat, enabling supplemental fat to increase energy density.
- Can enhance ration quality, and improve livestock performance and feed use efficiency.
- Can improve ration physical properties.
- Can reduce climatic heat stress effects.
- Can assist maintenance of dietary energy intake when DMI reduced.
- When approximately 4.0% DM or greater, may enable ionophores to be deleted without production loss.

- Allows quality to be conveniently maintained with a satisfactory infrastructure, an adhered to quality control program, and use of antioxidants.

Threats

- May contain contaminating toxins or chemicals.
- Community may perceive (incorrectly) an association with threat to be a Bovine Spongiform Encephalopathy carrier.

4.2 COMPARATIVE FEEDSTUFF EVALUATION

Efficient animal production demands a diet containing feedstuffs that address the animal's requirements for all essential nutrients. An individual feedstuff is finally evaluated with regard to its contribution to the total diet requirements; its comparative cost with alternative nutrient sources, and the particular attributes or advantages it offers. Nutrient energy cost will be an important consideration.

Historically, feedstuffs have been compared or evaluated primarily on their ability to supply energy to animals, since:

- energy is required in larger amounts than any other nutrient,
- energy is most often the limiting factor in animal production, and
- energy is the major cost associated with feeding animals.

Fats and oils are the most energy dense feedstuff. The cost of metabolisable energy (ME) is determined for a probable range of costs for fats and oils applying to NRC (1996) estimates of ME (Table 4.1).

TABLE 4.1 The cost of ME ($/100MJ) sourced from fats and oils for a range of costs

Fats and Oils ($/tonne As Is)	Dry Matter (%)	Fats and Oils ($/tonne DM)	ME[a] ($/100MJ)
250.00	99.00	252.53	0.83
350.00	99.00	353.54	1.16
450.00	99.00	454.55	1.49
550.00	99.00	555.56	1.82
650.00	99.00	656.57	2.15
750.00	99.00	757.58	2.48

[a] Costs based on NRC (1996) estimates of ME for fat at 30.54MJ/kg (refer Table 3.3)

The comparative values of alternative commonly used feedstuffs supplying energy at the same costs are then compared (Table 4.2). These tables can be customised to individual situation requirements, or to incorporate the estimates of Zinn *et al* (1998a, personal communication; refer 3.3.1).

TABLE 4.2 Comparative feedstuff values for a range of ME costs

FEEDSTUFF		Metabolisable Energy (Indicative DM Basis)		Dry Matter	Equivalent Feedstuff Costs ($/tonne As Is)					
Name	**Description**	**Range MJ/kg**	**Assessed MJ/kg**	**%**	**ME** $0.83/100 MJ	**ME** $1.16/100 MJ	**ME** $1.49/100 MJ	**ME** $1.82/100 MJ	**ME** $2.15/100 MJ	**ME** $2.48/100 MJ
FATS & OILS		30.5 [a]	30.5	99	250.00	350.00	450.00	**$550**	**$650**	**$750**
Barley	Grain	12.7_13.7	13.0	88	95.00	132.00	170.00	208.00	246.00	284.00
Maize	Grain	13.5_14.2	13.7	88	100.00	140.00	179.00	219.00	259.00	299.00
	Silage	9.2_11.3	10.3	37	32.00	44.00	57.00	69.00	82.00	95.00
Sorghum	Grain	11.0_13.4	12.0	88	87.00	122.00	157.00	192.00	227.00	262.00
Wheat	Grain	13.0_14.0	13.3	88	97.00	135.00	174.00	213.00	252.00	290.00
Molasses		10.9_12.7	11.0	77	70.00	98.00	126.00	154.00	182.00	210.00
Cottonseed	Whole	14.2_14.8	14.5	92	110.00	154.00	199.00	243.00	287.00	331.00
	Meal	11.2_12.2	11.7	90	87.00	122.00	157.00	192.00	226.00	261.00
Lucerne	Hay, Spring	8.4_10.0	9.2	90	68.00	96.00	123.00	151.00	178.00	205.00
	Hay, Summer	7.2_8.4	7.8	90	58.00	81.00	104.00	128.00	151.00	174.00

[a] Based on NRC (1996) estimate of ME for fat at 30.54 MJ/kg (refer Table 3.3)

Table 4.2 illustrates that when all other factors are equal, energy can be sourced at the same cost (ie. $1.49/100MJ) when fats and oils are $450/tonne, barley grain $170/tonne, maize grain $179/tonne, maize silage $57/tonne and so on, based on the assumptions made. Similarly, when fats are $450/tonne, a cheaper source of energy would be barley grain at less than $170/tonne. A more expensive source would be when barley grain exceeds $170/tonne, and so on.

4.3 PRACTICAL ASPECTS OF FEEDING FATS AND OILS

The feedgrade fats and oils are readily available in three forms, namely oilseeds, commodity fats and oils, and specialty fats (refer 1.2). Some characteristics of commonly used sources of these fats are listed in Table 4.3.

TABLE 4.3 Characteristics of commonly used sources of fats and oils (DM basis)

FEEDSTUFF	FAT %	PROTEIN %	FIBRE * %	COMMENTS
OILSEEDS				
White cottonseed	18-23	20-25	28-34	With lint or "fuzzy", may bridge in equipment.
Soybeans	18-20	38-42	10-11	Heat treating adds ruminal protection.
COMMODITY FATS				
Tallow	95-100	none	none	Solid at room temperature.
Yellow grease	95-100	none	none	Semi-soft at room temperature.
Animal/vegetable blends	95-100	none	none	Usually liquid at room temperature.
SPECIALTY FATS				
Megalac	80	none	none	Calcium salts of palm oil fatty acids.
Energy booster **	99	none	none	Prilled, relatively saturated fatty acids.
Booster fat	90	none	none	Tallow and protein in an alginate matrix.
Carolac	98	none	none	Hydrogenated tallow, prilled.

* Acid Detergent Fibre
** The products Golden Flake and Bergafat are similar
Source: After Emery and Herdt (1991)

White cottonseed containing 18.0-23.0% fat is widely available in areas adjacent to Australian cotton production areas, frequently at reasonable cost. Their cost, palatability and acceptability, convenience of handling and relative inertness in the rumen, frequently places them as the first choice of supplemental fat. White cottonseed also contributes protein and an effective form of fibre to the ration and has been a satisfactory ration feedstuff to 20.0% of DMI. Similarly, sunflower seeds contain 35.0 to 40.0% oil and the whole seed may be fed to 5.0% of DMI.

The commodity fats and oils, the subject of this study, are commonly the practical form of supplemental fat in addition to, or in the absence of, oilseeds when reasonably costed. Tallow, yellow grease and blends of animal and vegetable fats are commonly available to the Australian feedlot industry, frequently at reasonable comparative costs, and are frequently the second preferred form of fat supplementation.

Costs of commodity fats and oils fluctuate in relation to international markets, the use site locality, and order size. Their animal acceptability may vary with source. Commodity fats are subject to oxidation and rancidity and need care in handling and protection with antioxidants. With an established handling infrastructure they may typically supplement a ration at 2.0-6.0% inclusion levels, having due regard to total dietary (ie. from all nutrient sources) fat level. Whilst a number of researchers have been unable to define the maximum or optimum tolerable total dietary fat level (it is subject to a range of influences) an amount of up to 8.0% appears satisfactory (refer 3.2.1).

The specialty fats are products treated to make them more ruminally inert. Treatments include forming fine particles of solid fatty acids, encapsulation, or the formation of calcium soaps. These treatments are expensive. However they are (it is claimed) able to be fed after the limits of feeding oilseeds and commodity fats have been attained. Their feeding is usually restricted to about 2.0% of DMI. Their cost is such that if their use is warranted, it is after the scope for using oilseeds and commodity fats and oils has been fully exploited (Emery and Herdt, 1991).

It is generally agreed diets supplemented with fat, where total dietary fat exceeds 6.0%, should have calcium and magnesium levels increased to minimum 0.7% and 0.3% of dry matter respectively, increasing with higher dietary fat levels to 0.9% and 0.35% (refer 3.2.2).

4.4 SUPPLY SOURCES

The *Directory of Australian Renderers* (MLA 1998) is appended to aid the sourcing of fats and oils in Australia. This lists rendering interests and their product details, and while possibly not complete is the most comprehensive published compilation of this information. This is accompanied by details of the traders and broker members of the Australian Renderers Association Inc, and their product details (Appendix 3).

4.5 QUALITY STANDARDS

The standards for trading fats and oils in Australia are largely based on the practices of those supplying traditional markets, rather than the intensive livestock industry.

For the Australian feedlot industry, the principal quality considerations can be simply defined.

- Purity – fat proportion and its composition as it might affect nutrient energy value
- Stability – rancidity as it might affect livestock acceptability
- Contaminants – as they might affect animal health and meat products
- Consistency – delivery to delivery, as it might affect livestock acceptability

Product Purity is indicated by the MIU assessment to determine non-fatty matter present, and the TFA measuring the composition of the fat source. Acceptable limits might be MIU maximum 1.0% (absolute maximum 1.5%) and TFA minimum 90.0%, after which discounts might be applied. Whilst sometimes controversial, it has been concluded FFA levels *per se* have little influence on the feeding value of fat for feedlot cattle, other than that their high level presence may cause concern about oxidative rancidity (refer 3.3.2).

Stability which refers to the state of oxidative rancidity may be forewarned by high FFA levels indicating improper storage and/or handling of the fat. Antioxidants need to be added to all feed fats to prevent rancidity, particularly in the presence of high FFA. The current state of oxidative rancidity is indicated by the PV (properly handled fat should be ≤10; not rancid sample ≤5), or, as rancidity can rapidly change, simply by smell (refer 3.3.2).

Contaminants including heavy metals, pesticides, toxic chemicals and other prohibitive substances, are to be avoided. The supplier should certify every shipment to be contaminant free (refer 3.3.2; 3.4).

Consistency of product quality from delivery to delivery is desirable for maximum animal acceptance and performance.

4.6 INFRASTRUCTURE

The storage, receival and delivery infrastructure to handle fats and oils should be robust, simple and adequate with prime consideration given to preserving product quality. Whilst incorporating specific design features, the manufacture and installation is generally within the capabilities of a range of light industrial manufacturing businesses throughout rural Australia.

A comprehensive overview of liquid ingredient handling highlighting a range of design and construction aspects has been compiled by Moorhead (1994) and is appended (Appendix 4).

Additionally, the Australian feedlot industry experience has identified prime local design and construction considerations in the areas of:

- storage
- receival (carrier vehicle to storage)
- delivery (storage to mixer), and
- materials.

Storage

Deliveries will be generally in bulk tanker loads. Storage volumes need be sized to contain minimum 1.5 tanker loads, and adequate to meet requirements for holiday periods and extended non delivery periods for the operation concerned.

The specific gravity of fats and oils approximates 0.9. Their weight is thus 90.0% per unit of volume of that for water, necessitating volumes which exceed those required for the same weight of water by at least 10.0%. Storages should be vented to minimise condensation.

Storages need to allow for both the heating and the ability to bleed off from the bottom, water and impurities. These requirements can be satisfactorily addressed with a cone bottom storage tank, with sides extended to ground base. This structure contains a water bath below the product storage which is able to be electrically or steam heated with thermostat control. The lower fat storage area is further heated with an external insulated wrap-around panel coil covering some 1.5m of storage bottom, or with internal pipe coils circulating water for the lower 0.25-0.5m of storage area. Bath water is most efficient.

Product draw off should be at a point above the bottom of storage. Water and sludge bleed off should be at the lowest point of storage, with provision externally for a sizeable removable catch container.

Whilst Australia experiences overall a generally mild climate the feedlot industry is such that the infrastructure needs the capacity to receive, store, and deliver product reliably at all times and in all weathers. The infrastructure needs to always work even under the most adverse climatic conditions (eg. dawn, mid winter) and at the most inopportune times (eg. public holidays). It needs to always work.

Receival, and Delivery

A system of pipes and valves can enable the same pump to unload bulk carrier and deliver product to mixer. Pump capacity should provide for rapid receival, and a delivery rate to achieve adequate ration compilation, mixing and feeder plant turnaround.

Slow revving, high capacity, positive displacement pumps with low wear, non corrosive pins and bushes, positioned to be flood fed by storages work well.

Pump and delivery lines can be heated with hot water, steam tubing, or electrical tracing, and insulated. They should additionally be fitted with periodic air taps for applying compressed air to clear any blockage, and to periodically blow clean.

Outlet delivery at mixer may be by manifold or splash plates with one of a number of methods of controlling drips.

Ball valves, appropriate for automatic operation are satisfactory.

There may be spillage about the delivery area where hoses connect to pump and truck. Ideally this area should be a concrete surface able to be easily cleaned and drained away.

Materials

The materials used throughout need to address the specific properties of fats and oils and their storage requirements.

Bronze, brass and copper based metals are to be avoided to minimise fat and oil oxidation.

Tank and pipe materials, if of carbon steel for economy, need to be of a substantial grade to provide for wear and normal corrosion. Welded joints and flanged joints are preferable to threaded connections, and should use similar metal materials to minimise corrosion.

4.7 BOVINE SPONGIFORM ENCEPHALOPATHY

Australia is free of Bovine Spongiform Encephalopathy (BSE) and all other Transmissible Spongiform Encephalopathy (TSE) and meets the freedom provisions of the *Office International des Epizooties* (OIE) Animal Health Code for BSE as revised May 1997. There has been no clinical case of BSE in Australia. The disease is notifiable, and an effective surveillance and monitoring system is practised (Murray and Wilkinson, 1997).

There is no restriction to the use of animal fat in Australian stockfeeds.

5. GUIDELINES FOR THE USE OF COMMODITY FATS AND OILS IN THE AUSTRALIAN CATTLE FEEDLOT INDUSTRY

5.1 OVERVIEW

Fats and oils, the most energy dense feedstuff, are potentially a valuable energy supplement to enhance cattle feedlot rations when favourably costed, and, compatible with the basal dietary components.

The final evaluation of their contribution to a feeding regime is a cost/benefit assessment, acknowledging their nutritional, physical and intangible attributes in comparison to those from alternative sources.

5.2 GUIDELINES

There are several fundamental aspects contributing to the successful use of fats and oils in cattle feedlot rations.

Source

The source supply needs to be reliable and able to deliver a consistent suitable quality product. Specifications should address **product purity** (MIU, and TFA), **stability**, as in rancidity (FFA, antioxidants, smell), **contaminants** (certification as to freedom from contaminants), and, an assurance as to the **consistency** of delivery to delivery, and cost.

Antioxidants should be added at source, at the latest point prior to dispatch and with the supplier's assurance.

(refer 2.2; 4.5)

Cost

The contribution fats and oils make to a feeding regime can be initially assessed applying a balancing least-cost ration assessment. This will recognise fat's nutrient energy contribution and cost, acknowledging the fat content of all dietary components. It is possible an oilseed such as white cottonseed may supply a range of nutrients including energy from fat at less cost.

The assessment should recognise the declining marginal energy values of a supplemental fat as the inclusion level increases, and total dietary fat increases. A reasonable maximum total dietary fat level appears in the order of 8.0%. When exceeding 5.0% suggested dietary calcium and magnesium levels are minimum 0.9% and 0.3% respectively.

(refer 3.2.2; 3.3.1)

Associated Benefits

There are significant additional benefits associated with a fat supplement when assessing its overall contribution to feedlot rations. These include the following:

- Increased diet energy density, and reduced waste volume.
- Improved animal performance.
- Improved production efficiency, and resultant associate improved resource (physical, financial) use efficiency.
- Improved ration properties (reduced dust, waste) and appeal.
- Lubricating effect benefiting plant and equipment and reducing mechanical energy.
- The minimisation of adverse climate environmental influences on intake (heat, cold).
- Stabilising effect on ration quality.

(refer 3.2.3; 3.3.1; 3.4; 4.1)

Infrastructure

A specific purpose infrastructure will be necessary to handle the fat and oil feedstuff delivered in bulk. This should incorporate the following features:

- Suitably heated storage sized equivalent to 1.5 to 2.0 deliveries, say 40 tonne, with sludge drain-off ability.
- Pump(s) adequate to unload delivery trucks, recirculate product on site (if necessary), and delivery to mixer (batch, truck) with considerable haste and reliability.
- Transfer pipes all suitably heated, and with air taps to free possible blockages.

The design would recognise the necessity to safeguard the feedstuff from contamination with moisture, and yellow metals which may adversely affect fat quality in storage.

(refer 3.3.2; 3.4)

Specifying soft fats such as vegetable products (when available) may enable more ease in handling fats, and simplify infrastructure needs in smaller installations.

Product Monitoring

A quality control program is desirable to monitor the delivered product, particularly in regard to purity (MIU, TFA), stability (rancidity, smell, antioxidants), and potential contaminants (samples tested at a suitable NATA laboratory). A TFA test further guides the feedlot as to fat purity, and assists energy value determinations.

Sludge accumulated in storage needs to be regularly drained off to minimise its adverse effect on stability.

(refer 3.3.2; 3.4)

BIBLIOGRAPHY

Backlog, B.P. (1995). Tallow as a raw material – its place in the world. The Original Recyclers, Proceedings Third International Symposium, Sydney, 1995. Australian Renderers Association, Sydney.

Bartle, S.J., Preston, R.L., and Miller, M.I. (1994). Dietary energy source and density: effects of roughage source, roughage equivalent, tallow level, and steer type on feedlot performance and carcase characteristics. *J.Anim.Sci.,* **72**:1943.

Bock, B.J., Harman, D.L., Brandt, R.T., and Schneider, J.E. (1991). Fat source and calcium level effects on finishing steer performance, digestion, and metabolism. *J.Anim.Sci.,* **69**:2211.

Boucqué, C.V., Fiems, L.O., Cottyn, B.G., and Buysse, F.X. (1990). Effect of dietary fats on animal performance, carcase quality and lipid composition of kidney fat in beef bulls. *J.Anim.Physiol. a. Anim.Nutr.* **63**:213.

Brandt, R.T. (1992). Fats in diets for feedlot cattle. Southwest Nutrition and Management Conference, Proceedings : 27. U.Arizona, Tucson.

Brandt, R.T. (1995). Use of supplemental fat to optimise net energy intake in feedlot cattle. Symposium: Intake by Feedlot Cattle. Oklahoma State University, Stillwater.

Brandt, R.T., and Anderson, S.J. (1990). Supplemental fat source affects feedlot performance and carcase traits of finishing yearling steers and estimated net energy value. *J.Anim.Sci.,* **68**:2208.

Brandt, R.T., and Pope, R.V. (1992). Influence of fat and monensin levels on performance of finishing steers. Kansas Agricultural Experiment Station Report of Program 651:4. Kansas State University, Manhattan.

Brandt, R.T., Anderson, S.J., and Elliot, J.K. (1988). Influence of ionophore rotation and fat level on performance of finishing heifers. Kansas Agricultural Experiment Station Report of Program 555:25. Kansas State University, Manhattan.

Brandt, R.T., Nagaraja, T.G., and Elliot, J.K. (1991). Influence of supplemental fat and monensin plus tylosin on performance and carcase traits of finishing steers. Kansas Agricultural Experiment Station Report of Program 623:96. Kansas State University, Manhattan.

Brethour, J.R. (1984). Adding fat to milo-based steer finishing rations. Kansas Agricultural Experiment Station Report of Program 452:15. Kansas State University, Manhattan.

Brethour, J.R., Riley, J., and Lee, B. (1986). Adding fat and/or sodium bicarbonate to steer finishing rations that contain wheat. Kansas Agricultural Experiment Station Report of Program 496:4. Kansas State University, Manhattan.

Carrica. J.M., Freeman, A.S., and Brandt, R.T. (1991). Effect of protein level and added fat in finishing diets on feedlot performance and carcase characteristics of beef steer calves. *J.Anim.Sci.,* **69**:476.

Clary, E.J., Brandt, R.T., Harman, D.L., and Nagaraja, T.G. (1993). Supplemental fat and ionophores in finishing diets: Feedlot performance and ruminal kinetics in steers. *J.Anim.Sci.,* **71**:3115.

Clary, E.M., Brandt, R.T., Anderson, S.J., Pope, R.V., and Elliot, J.K. (1991). Effect of fat and ionophores on performance of finishing cattle fed 90.0% concentrate diets. *Abstracts, Midwestern Section, American Society of Animal Science,* 156. Des Moines, IA.

Clinquart, A., Micol, D., Brundseaux, C., Dufrasne, I., and Istasse, L. (1995). Utilisation des matiéres grasses chez les bovins á l'engraissement (Use of fat in fattening diets for cattle). *INRA Productions Animales* **8**:29.

Cole, N.A., and Hutcheson, D.P. (1987). Influence of receiving diet fat level on the health and performance of feeder calves. Nutrition Reports International **36**:965.

Doreau, M., and Chilliard, Y. (1997). Digestion and metabolism of dietary fat in farm animals. *British J. Nutrition* **78**: Suppl.1,515.

Emery, R.S., and Herdt, T.H. (1991). Lipid Nutrition. *The Veterinary Clinics of North America: Food Animal Practice*. (Eds. Sniffen, C.J., and Herdt, T.H.) **7** :341. W.B. Saunders Company, Philadelphia.

Engstrom, D.F., Goonewardene, L.A., Grimson, R.E., McKinnon, P.J., Stilborn, R.P., and Volek, R. (1994). Effects of feeding added protein and fat on feedlot performance and carcase quality in large frame steers. *Can. J.Anim.Sci.* **74**:547.

Ensminger, M.E., Oldfield, J.E., and Heinemann, W.W. (1990). *Feeds and Nutrition*. Second Ed. The Ensminger Publishing Company, Clovis, California.

Gramlich, S.M., Brandt, R.T., and Pope, R.V. (1990). Dose response to supplemental fat by finishing steers. Kansas Agricultural Experiment Station Report of Program 592:4. Manhattan. Kansas State University.

Grummer, R.R. (1996). Utilising rendered products: ruminants – fats and greases. *The Original Recyclers* (Eds Franco, D.A., and Swanson, W.) Fats and Protein Research Foundation, Inc. Illinios.

Hale, W.H. (1986). Fat in the diets of growing finishing cattle. Proceedings of the Southwest Nutrition Conference, 46. U.Arizona, Tucson.

Hayward, K. (1991). Optimum utilisation of animal fats and proteins in poultry and pig diets. Animal Hygiene and Nutrition Proceedings, International Symposium, Sydney, 1991. Australian Renderers Association, Sydney.

Henderson, C. (1973). The effects of fatty acids on pure cultures of rumen bacteria. *J.Agric.Sci.,* (Camb) **81**:107.

Huerta-Leidenz, N.O., Cross, H.R., Lunt, D.V., Pelton, L.S., Savell, J.W., and Smith, S.B. (1991). Growth, carcase traits, and fatty acid profiles of adipose tissues from steers fed whole cottonseed. *J.Anim.Sci.,* **69**:3665.

Huffman, R.P., Stock, R.A., Sindt, M.H., and Slain, D.H. (1992). Effect of fat type and forage level on performance of finishing cattle. *J.Anim.Sci.,* **70**:3889.

Jenkins, T.C., and Fotouki, N. (1990). Effects of lecithin and corn oil on site of digestion, ruminal fermentation and microbial protein synthesis in sheep. *J.Anim.Sci.,* **68**:460.

Krehbiel, C.R., McCoy, R.A., Stock, R.A., Klopfenstein, D.H., and Huffman, R.P. (1995a). Influence of grain type, tallow level, and tallow feeding system on feedlot cattle performance. *J.Anim.Sci.,* **73**:2916.

Krehbiel, C.R., Stock, R.A., Shain, D.H., Richards, C.J., Ham, G.A., McCoy, R.A., Klopfenstein, T.J., Britton, R.A., and Huffman, R.P. (1995b). Effect of level and type of fat on subacute acidosis in cattle fed dry rolled finishing diets. *J.Anim.Sci.,* **73**:2438.

Maczulak, A.E., Dehority, B.A., and Palmquist, D.L. (1981). Effects of long-chain fatty acids on growth of rumen bacteria. *Appl. and Envr. Microbiol.,* **42**:856.

MLA (1998). Directory of Australian Renderers. Meat and Livestock Australia, Sydney.

Moore, J.A., Swingle, R.S., and Hale, W.H. (1986). Effects of whole cottonseed, cottonseed oil or animal fat on digestibility of wheat straw diets by steers. *J.Anim.Sci.,* **63**:1267.

Moorhead, T.G. (1994). Liquid ingredient handling. *Feed Manufacturing Technology IV,* (Ed R.R. McEllhiney), **17**:185. American Feed Industry Association, Inc., Arlington, Virginia.

MRC (1993). The meatmeal and tallow industry and its markets M258. Meat Research Corporation, Sydney.

MRC (1995). Rentech Compendium (Rendering Technology Audit) M507. Meat Research Corporation, Sydney.

MRC (1996). The Meatmeal and Tallow Industry and its Markets – Strategic Planning Update M829, Meat Research Corporation, Sydney.

Murray, G., and Wilkinson, S. (1997). Surveillance: Protecting Australia's Integrity. Proceedings, Fourth International Symposium, Melbourne, 1997. Australian Renderers Association, Sydney.

NACMA (1996). Agricultural Commodities: Fats and Oils. National Agricultural Commodities Marketing Association Incorporated. Wilberforce, NSW.

NRC (1996). National Research Council. *Nutrient Requirements of Beef Cattle*. Seventh Ed. National Academy Press: Washington DC.

O'Brien, M. (1993). Product price relationships in commercial animal feeds. Animal Hygiene and Nutrition. Proceedings, Second International Symposium, Sydney, August 1993. Australian Renderers Association, Sydney.

O'Kelly, J.C. (1987). Influence of dietary fat on some metabolic responses of cattle to hyperthermia induced by heat exposure. *Comp. Biochem. Physiol*. **87A**:677.

Palmquist, D.L. (1992). Fat in dairy cattle rations. Directors Digest 237. Fats and Protein Research Foundation Inc, Illinios.

Palmquist, D.L. (1994). The role of dietary fats in efficiency of ruminants. *J.Nutru.* **124**:1377S.

Palmquist, D.L., and Jenkins, T.C. (1980). Fat in lactation rations: review. *J.Dairy.Sci.,* **63**:1.

Tapp, N. (1996a). An overview of co-products. Australian Meat and Livestock Review, April 1996:8. AMLC, Sydney.

Tapp, N. (1996b). Meat co-products – Tallow. Australian Meat and Livestock Review. May 1996:10. AMLC, Sydney.

Tesfa, A.T., Tuori, M., and Syrjala-Qvist, L. (1992). The influences of partial replacement of barley with dietary fat sources on growth and feed conversion efficiency of growing bulls. *Agricultural Science in Finland* **1**:267.

USDA (1997). Livestock and Poultry: World markets and trade. Foreign Agricultural Service, Circular Series FLandP 2-QT:84, USDA, Washington.

White, T.W.L., Bunting, L.D., Sticker, L.S., Hembry, F.G., and Saxton, A.M. (1992). Influence of fish meal and supplemental fat on performance of finishing steers exposed to moderate or high ambient temperatures. *J.Anim.Sci.* **70**:3286.

Zinn, R.A. (1986). Influence of method of fat supplementation on feeding value of fat for feedlot cattle. California Feeders Day Report 1986:65. Dept of Animal Science, U.California, El Centro.

Zinn, R.A. (1987). Influence of calcium source on digestive function and feedlot performance of steers fed a high fat finishing diet. California Feeders Day Report 1987:136. Dept of Animal Science, U.California, El Centro.

Zinn, R.A. (1988). Comparative feeding value of supplemental fat in finishing diets for feedlot steers supplemented with and without monensin. *J.Anim.Sci.,* **66**:213.

Zinn, R.A. (1989a). Influence of level and source of dietary fat on its comparative feeding value in finishing diets for steers: Feedlot cattle growth and performance. *J. Anim. Sci.,* **67**:1029.

Zinn, R.A. (1989b). Influence of level and source of dietary fat on its comparative feeding value in finishing diets for feedlot steers: Metabolism. *J.Anim.Sci.,* **78**:1038.

Zinn, R.A. (1989c). Urea may be superior to SBM as a N source in fat supplemented steam-flaked corn based finishing diets for feedlot cattle. University of California. IVAC Research Update 1:6. Dept of Animal Science, U.California, El Centro.

Zinn, R.A. (1992a). Comparative feeding value of supplemental fat in steam-flaked corn- and steam-flaked wheat-based finishing diets for feedlot steer. *J.Anim.Sci.,* **70**:2959.

Zinn, R.A. (1992b). Feeding value of fat in diets for feedlot cattle. Directors Digest 241. Fats and Protein Research Foundation, Inc. Illinios.

Zinn, R.A. (1994). Effects of excessive supplemental fat on feedlot cattle growth and performance and digestive function. *Professional Animal Scientist* **10**:66.

Zinn, R.A. (1995). Characteristics of digestion of linted and lint-free cottonseed in diets for feedlot cattle. *J.Anim.Sci.,* **73**:1246.

Zinn, R.A. (1996a). Fat quality and feeding value of fat for feedlot cattle. Technical Services Bulletin 283. Fats and Protein Research Foundation, Inc. Illinios.

Zinn, R.A. (1996b). Feeding value of cotton by-products in diets for feedlot cattle. Proceedings, Southwest Nutrition and Management Conference. U.Arizona, Tucson.

Zinn, R.A., and Borques, J.L. (1993). Influence of sodium bicarbonate and monensin of utilisation of a fat-supplemented, high energy growing finishing diet by feedlot steers. *J.Anim.Sci.,* **71**:18.

Zinn, R.A., and Plascencia, A. (1993). Interaction of whole cottonseed and supplemental fat on digestive function in cattle. *J.Anim.Sci.,* **71**:11.

Zinn, R.A., and Plascencia. A. (1996). Effects of forage level on the comparative feeding value of supplemental fat in growing-finishing diets for feedlot cattle. *J.Anim.Sci.,* **74**:1194.

Zinn, R.A., and Shen, Y. (1996). Interaction of dietary calcium and supplemental fat on digestive function and growth performance in feedlot steers. *J.Anim.Sci.,* **74**:2303.

Zinn, R.A., Hansaker, M.E., and Ware, R.A. (1998a). "ZAP 1.16 – Visual Feedlot Consultant". Registered Software 1997-98, VeraSys, LLC.

Zinn, R.A., Plascencia, A., and Shen, Y. (1998b). Influence of method of supplementation on the utilisation of supplemental fat by feedlot steers (unpublished). Dept of Animal Science, U.California, El Centro.

Zinn, R.A., Shen, Y., Baragas, R., Moanto, M., Alvarez, E., and Ramirez, E. (1998c). Effects of dietary calcium levels on growth performance and digestive function of cattle fed a high fat finishing diet. (unpublished) Dept of Animal Science, U.California, El Centro.

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APPENDICES

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APPENDIX 1

Study Terms of Reference

APPENDIX 2

Fats and Other Lipids – An Overview

The following overview, extracted from "Feeds and Nutrition", Chapter 4 - Nutrients/Metabolism, (Ensminger *et al* 1990), provides a background to fats and other lipids.

FATS AND OTHER LIPIDS

Lipids is an all-embracing term referring to compounds that are soluble in chloroform, benzene, petroleum, or ether. It includes fats, oils, waxes, sterols, and complex compounds such as phospholipids and sphingolipids.

Lipids, like carbohydrates, contain the three elements – carbon, hydrogen, and oxygen.

Not all lipids are fats, but all fats are lipids; so, the two terms are used interchangeably. Fats and oils are differentiated on the basis of melting points; fats are solid at room temperature, while oils are liquid. As livestock feeds, fats and oils function much like carbohydrates in that they serve as a source of heat and energy and for the formation of fat. Because of the larger proportion of carbon and hydrogen however, fats and oils liberate more energy than carbohydrates when digested, furnishing an oxidation approximately 2.25 times as much heat or energy per pound as do the carbohydrates. A smaller quantity of fat is required, therefore, to serve the same function. Common belief to the contrary, animals can tolerate a rather high-fat content in the ration. As evidence of this, sucklings normally handle a relatively large amount of fat, for milk contains 25.0 to 40.0% of this nutrient on a dry matter basis. Also, except for the soft pork problem, no apparent difficulty is encountered in feeding hogs a rather high-fat ration, such as results when large quantities of peanuts or soybeans are fed.

A small amount of fats in the ration is desirable, as these fats are the carriers of the fat-soluble vitamins. Fortunately, normal farm rations contain ample quantities of these nutrients.

Classification of Lipids

Lipids are often classified into three major groups: (1) simple lipids; (2) compound lipids; and (3) derived lipids. When fatty acids are esterified with alcohols, **simple lipids** result. If compounds such as choline or serine are esterified to alcohols in addition to fatty acids, **compound lipids** result. The third type of lipid, **derived lipids**, results from the hydrolysis or enzymatic breakdown of simple and compound lipids. The Table A-1 classifies lipids and provides some examples and characteristics of each of them.

TABLE A-1 - Classification of Lipids

Type of Lipid	Example	Chemistry	General Comments
Simple lipids:			
Neutral fats	Triglycerides (triecylglycerols)	Esters of fatty acids with glycerol; ratio of three fatty acids to one glycerol	Most abundant lipids in nature. Mixed triglycerides (those in which at least two fatty acids are different) account for 98.0% of the fats in feeds and over 90.0% of fat in the body.
Waxes	Beeswax	Esters of fatty acids with high-molecular-weight alcohols other than glycerol. This group includes the esters of cholesterol, vitamin A, and vitamin D.	More important in commerce than in animal nutrition; occur widely in cuticle of leaves and fruit.
Compound lipids: Phospholipids	Lecithins Cephalins Lipositols	Compounds of neutral fat, a phosphoric acid, and a nitrogenous base (choline, ethenclamine, or serine); water-soluble.	Lecithins are largest group of phospholipids. Lecithin may be obtained from egg yolks or soybeans.
Glycolipids	Cerebrosides Gangliosides	Sugar (carbohydrate)-containing fatty acids plus nitrogen.	Sugar can be glucose or gelactose; found in nervous tissue; component of cell membrane.
Lipoproteins	Chylomicrons Very low density lipoproteins (VLDL) Low density lipoproteins (LDU) High density lipoproteins (HDU)	They all contain protein, triglycerides, phospholipids, and cholesterol; but in varying amounts.	The lipoproteins, synthesised in the liver, are composed of about $^1/4$ to $^1/3$ protein, with the remainder lipids. Means of transporting lipids in the blood.
Derived lipids: Fatty acids	Palmitic acid Oleic acid Stearic acid Linoleic acid	Generally have one acid group (COOH); may be saturated, or unsaturated – contain one or more double bonds.	In most cases, there is an even number of carbon atoms in the naturally-occurring fatty acids. There are few odd-numbered carbon atom fatty acids in nature. Release of fatty acids from triglyceride releases glycerol.
Steroids	Cholesterol Ergosterol Cortisol Bile acids Vitamin D Androgens, estrogens, and progesterone	Derivatives of the perhydrocyciopenten-o-penanthrene nucleus (chemical structure is a series of rings).	One of the most studied classes of lipids. Collectively many of these are referred to as steroid hormones – hormones of the adrenal gland, testes, and ovaries.
Hydrocarbons	Terpenes	Compounds of hydrogen and carbon only.	Includes a series of oils (such as camphor), resin acids, and plant pigments. Beta-carotene is an example of an important terpene.

Characteristics of Fats

Triglycerides – the combination of three fatty acid molecules and a glycerol molecule – account for about 98.0% of the fats in feed and over 90.0% of the fat in the animal body. The remainder of the diet and body fats is comprised primarily of phospholipids and cholesterol. Since triglycerides and their component fatty acids are so abundant in the diet and body, the discussion which follows centres around fatty acids and triglycerides.

FATTY ACIDS

Fatty acids are key components of lipids. They are called acids because of the carboxyl organic acid group (COOH) which they contain. Their degree of saturation and the length of their carbon chain determine many of the physical characteristics of lipids. Numerous triglycerides exist due to the variety of fatty acids which may bind with glycerol. The properties of fatty acids depend on their chemical characteristics, which follow.

Saturation – This refers to the ratio of hydrogen atoms to carbon atoms. The backbone of the fatty acid consists of a chain of carbon atoms joined by chemical bonds. When a single bond joins each pair of carbon atoms, carbon atoms within the chain have two hydrogen atoms joined to them and carbons at the end of the chain have three hydrogens. When carbon atoms are joined by double bonds, the carbon atoms within the chain are able to have only one hydrogen bound to them. Therefore, saturated fatty acids contain all possible hydrogen and no double bond between carbon atoms. Unsaturated fatty acids contain at least one double bond within the carbon chain (monounsaturated) or two or more double bonds within the carbon chain (polyunsaturated). Therefore, unsaturated fatty acids contain the same number of carbon atoms, but fewer hydrogen atoms than their saturated counterparts. Figure A-1 illustrates the concept of saturated and unsaturated.

SATURATED

```
 O H H H H H H H H H H H H H H H H H
 II I I I I I I I I I I I I I I I I
HO-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-H
   I I I I I I I I I I I I I I I I I
   H H H H H H H H H H H H H H H H H
```

(STEARIC ACID, $C_{18}H_{36}0_2$)

MONOUNSATURATED

```
 O H H H H H H H     H H H H H H H H
 II I I I I I I I    I I I I I I I I
HO-C-C-C-C-C-C-C-C-C=C-C-C-C-C-C-C-C-C-H
   I I I I I I I I I I I I I I I I I
   H H H H H H H H H H H H H H H H H
```

(OLEIC ACID, $C_{18}H_{34}0_2$)

POLYUNSATURATED

```
 O H H H H H H H     H     H H H H H
 II I I I I I I I    I     I I I I I
HO-C-C-C-C-C-C-C-C-C=C-C-C=C-C-C-C-C-C-H
   I I I I I I I I I I I I I I I I I
   H H H H H H H H H H H H H H H H H
```

(LINOLEIC ACID, $C_{18}H_{22}0_2$)

Figure A-1: Three fatty acids all composed of 18 carbons but different degrees of saturation or unsaturation. The = indicates a double bond and C stands for carbon, H for hydrogen, and O for oxygen

Most fatty acids in nature contain an even number of carbon atoms. The nomenclature is such that the following suffixes are used to describe the degree of unsaturation:

- Anoic – no double bond.
- Enoic – one double bond.
- Dienoic – two double bonds.
- Trienoic – three double bonds.
- Tetraenoic – four double bonds.
- Pentaenoic – five double bonds.

Iodine value (number) – Unsaturated fat readily unites with iodine; two atoms of this element will add to each double bond. Thus, in experimental work, the number of grams of iodine absorbed by 100g of fat – the iodine value – is an excellent criterion of the degree of unsaturation. In the past, the iodine test was commonly used when studying the soft pork problem – a problem caused when pigs are fattened on feeds rich in unsaturated fats, such as peanuts or soybeans. At the present time, the chief measure used in such determinations is the refractive index, as determined by a refractometer.

Fatty acids that are unsaturated have the ability to take up oxygen or certain other chemicals. This presents both advantages and disadvantages. The value of linseed oil and varnish is due to their high content of unsaturated fatty acids, by virtue of which oxygen is absorbed when they are exposed to air, resulting in a tough, resistant coating. On the other hand, because of their unsaturation, these fats often become rancid through oxidation, resulting in disagreeable flavours and odours which lessen their desirability as feeds. Moreover, oxidative rancidity in fats results in formation of unstable compounds called peroxides, which can destroy certain essential nutrients in the diet.

Rancidity – This is the oxidation (decomposition) primarily of unsaturated fatty acids resulting in disagreeable flavours and odours in fats and oils. This process occurs slowly and spontaneously, and may be accelerated by light, heat and certain minerals. Rancidity may be prevented through proper storage and/or the addition of antioxidants such as BHA (butylated hydroxyanisole). Some fats are naturally protected from oxidation due to the presence of vitamin E. Hydrogenation of fats (adding hydrogen to unsaturated fatty acids) increases their hardness and also lessens the threat of rancidity. This process has been used to improve the keeping quality of vegetable shortenings and lard.

Hydrogenation (hardening) – This process adds hydrogen to the double bonds of unsaturated fatty acids. It may be accomplished with hydrogen gas in the presence of a nickel catalyst. It also occurs in the rumen as a result of microbial activity. The result of hydrogenation is a harder fat because adding hydrogen increases the melting temperature. It may be used on animal or vegetable fats to produce fats with a desired hardness. Many vegetable oils are converted into a solid or semisolid form for use in shortenings and margarines. Hydrogenation is also known as hardening.

Hydrogenation has a drawback in that it converts the naturally-occurring *cis* fatty acids to *trans* fatty acids. The prefixes *cis* and *trans* refer to the orientation of the atoms around the double bond. The *trans* form of essential fatty acids does not function as an essential fatty acid in the body. Also, some researchers have found that (1) *trans* fatty acids are not as effective as their *cis* analogues in lowering blood cholesterol, and (2) fats rich in *trans* fatty acids appear to promote atherosclerosis.

The content of *trans* fatty acids generally increases with the extent to which a vegetable oil has been hydrogenated. For example, hard sticks of vegetable oil margarines may contain from 24.0 to 35.0% of *trans* acids, whereas lightly hydrogenated liquid oils usually contain 5.0% or less.

Carbon chain length – Another variable factor in the makeup of fatty acid molecules is the number of carbon atoms. Fatty acids are designated as having (1) short chains when the number of carbon atoms is six or less, (2) medium chains where there are eight or 10 carbon atoms, and (3) long chains when there are 12 or more carbon atoms.

Together, the degree of saturation and the length of the carbon chain influence the melting point of fats as shown in Table A-2. Short chain fatty acids tend to be more volatile, and acetic, propionic, and butyric acids are collectively called volatile fatty acids (VFA). There is a steady rise in melting point as the chain lengths increase. However, as the number of double bonds increases, the melting point decreases.

TABLE A-2 - The Chemistry of some Fatty Acids

Name	Structural Formula	Chain Length Nº. C atoms	Melting Point °C	Example of Source
Saturated				
Acetic	CH3CH00H	2	-	Vinegar
Propionic	CH3CH2C00H	3	-	Dairy products
Butyric	CH3(CH2)2C00H	4	-7	Coconut butter
Caproic	CH2(CH2)4C00H	6	-8	Coconut butter
Caprylic	CH3(CH2)8C00H	8	16	Coconut butter
Capric	CH3(CH2)8C00H	10	31	Coconut butter
Lauric	CH2(CH2)10C00H	12	44	Coconut, palm
Myristic	CH3(CH2)12C00H	14	54	Coconut butter, whale blubber
Palmitic[1]	CH3(CH2)14C00H	16	63	Palm, beef tallow, butter, lard, cottonseed oil
Stearic[1]	CH3(CH2)18C00H	18	70	Beef tallow, butter, lard
Arachidic	CH3(CH2)18C00H	20	76	Peanut oil
Lignoceric	CH3(CH2)22C00H	24	86	Beachwood tar
Monosaturated				
Palitoleic[1]	CH3(CH2)6CH=CH(CH2)7C00H	16	-	Menhaden (fish), chicken, beef tallow
Oleic[1]	CH3(CH2)7CH=CH(CH2)7C00H	18	13	Olive oil, peanut oil, egg
Polyunsaturated				
Linoleic[1]	CH3(CH2)4CH=CHCH2CH=CH(CH2)7C00H	18	-5	Safflower, soybean oil, corn oil
Linolenic	CH3CH2CH=CHCH2CH=CHCH2CH=CH(CH2)7C00H	18	-11	Linseed oil, soybean oil
1 Arachidonic	CH3(CH2)4CH=CHCH2CH=CHCH2CH=CHCH2CH=CH(CH2)3C00H	20	-50	Liver, egg

[1] Most abundant in animal lipids

Saponification value (number) – The combination of a fatty acid with an alkali, such as potassium or sodium hydroxide, forms soap. This reaction is called saponification. Besides forming soap, it is a method of evaluating the average length of the carbon chain in the fatty acids which constitute a fat. The test is performed by reacting fats with potassium hydroxide. The saponification number, or value, is the number of milligrams of potassium hydroxide required for the complete saponification of 1g of the fat. A high saponification value signifies a short chain length and vice versa.

Saponification may also occur in the alkaline medium of the intestine. For example, calcium may combine with free fatty acids.

Emulsification – Fats (oils) and water do not stay mixed, but often it is desirable for them to do so. Therefore, fats are often emulsified. Minute droplets of fats or oils are evenly distributed throughout a water-based solution. Emulsions are essential for the digestion, absorption, and transport of fats in the body. Emulsifying agents used to create emulsions include some fatlike and fat-derived substances such as monoglycerides (glycerol with one fatty acid), diglycerides (glycerol with two fatty acids), lecithin and the bile salts.

APPENDIX 3

Directory of Australian Renderers

The following directory is reproduced with the consent of Meat & Livestock Australia (MLA 1998).

APPENDIX 4

NACMA Agricultural Commodities – Fats and Oils

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APPENDIX 5

Liquid Ingredients Handling

The following overview, extracted from *Feed Manufacturing Technology IV*, Chapter 17 – Liquid Ingredient Handling (Moorhead 1994), provides a background to fats and oils handling infrastructure.