

The functional properties of fats and oils - A richness of diversity

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RESUMEN

Las propiedades funcionales de los aceites y grasas. Una gran diversidad

La importancia de los aceites y grasas se deriva de la funcionalidad que los mismos pueden conferir, debido a sus características químicas y estructurales. Una propiedad clave de los lípidos es su relativa insolubilidad en agua, gracias a su larga región no polar. Sin embargo, los lípidos también contienen grupos con una cierta polaridad. La combinación de estas características de compuestos simultáneamente polares y no polares, así como los diferentes grados de las mismas que pueden encontrarse, son las que les confieren el amplio rango de propiedades funcionales que poseen y su extraordinario valor. En este volumen de Grasas y Aceites se revisan algunas de estas propiedades funcionales. Los Editores esperan que esta edición especial de la Revista constituya una referencia obligada en relación con el estado actual de los conocimientos y las aplicaciones de los temas que se han incluido.

PALABRAS-CLAVE: Aceites — Compuestos anfífilicos — Grasas — Propiedades funcionales.

SUMMARY

The functional properties of fats and oils - A richness of diversity

A part of the importance of fats and oils derives from the functional properties that they confer to the foods. This is a consequence of their chemical nature and structural features. Lipids are relatively insoluble in water because their large non-polar region. However, they also contain groups with some degree of polarity. The combination of these polar and non-polar groups and their variations is what gives the range of functional properties observed and what made them so valuable. This issue of Grasas y Aceites reviews some of the functional properties of fats and oils. The Editors hope that the studies included will provide an state of the art reference volume of present knowledge and applications in these areas.

KEY-WORDS: Amphiphilic compounds — Fats — Functional properties — Oils.

FATS AND OILS-A MAJOR INDUSTRY

The importance of fats and oils originates in the functionality that they can confer, this in turn arises from their chemical nature and the common structural

features that exist in all fats and oils. In the context of this review, the term fats and oils specifically excludes mineral products and applies to what are normally called lipids. Lipids are defined by The Condensed Chemical Dictionary (1) as: « An inclusive term for fats and fat derived materials. Includes all substances which: 1. are relatively insoluble in water but soluble in organic solvents..., 2. related either actually or potentially to fatty acid esters, fatty alcohols, sterols, waxes etc..., and 3. utilisable by the animal organism.»

Fats and oils cover a huge range of materials produced in vast tonnage every year. Table I gives world production figures for some major fats and oils. A more up to date analysis for the USA is given in Table II. The scale of consumption is huge and attests to the enormous importance of fats and oils to the global economy as well as the role that they play in our every day lives.

Table I

World production of fats and oils in thousands of metric tonnes (source Ref. 2)

OIL OR FAT	1985/86	1987/88	1989/90
Soya	14240	15530	16120
Cottonseed	3700	3593	3588
Groundnut	3324	3489	3787
Sunflower	6894	7557	7767
Rape	6246	7842	8025
Olive	1870	2198	1736
Coconut	3334	2937	3187
Palm	7294	8575	10920
Palm Kernel	992	1152	1421
Other Vegetable	2754	2965	2995
Butterfat	6493	5387	5344
Lard	5092	5386	5344
Tallow	6488	6773	6559

Table II
Oil and fat production in the United States for
1997 in thousands of metric tonnes
(source Ref. 3)

OIL OR FAT	Production
Cottonseed	551
Soya	7339
Corn	1014
Groundnut	76
Lard	171
Tallow (edible)	670
Coconut (refined)	162
Sunflower	29
Vegetable Oil Foods	129
Tall Oil	672
Tallow (inedible and grease)	2812
Tung	9
Fish	13
Safflower	9
Rapeseed (refined)	118

Table III gives a further analysis of the data from the US for edible and inedible fats and oils. The total consumption of edible products is two and a half times that of inedible products attesting to the role of the food industry as consumers of fats and oils and their overall importance in food products.

Table III
Consumption of fats and oils in edible and
inedible products for 1997. Figures are in
thousands of metric tons
(source Ref. 3)

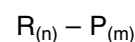
EDIBLE PRODUCTS	CONSUMPTION
Baking and Frying Fats	2555
Salad or Cooking Oil	3358
Margarine	780
Other Products	134
TOTAL	6827

INEDIBLE PRODUCTS	CONSUMPTION
Soap	255
Paint and Varnish	42
Feed	1190
Resins and Plastics	93
Lubricants	56
Fatty Acids	1053
Other Products	251
TOTAL	2941

FUNCTIONALITY

The origins of the functionality of fats and oils lies in the chemical constitution. As the definition given above implies a key feature of lipids is their relative insolubility in water, this arises because all lipid molecules have a common feature of containing a large non-polar region. This is highly variable and may itself contain a wide range of chemical species. However the second common feature of lipids is that they all contain a functional group or groups which have some degree of polarity. It is the combination of the polar and non-polar and the variations that are possible within these that give the range of functional properties that are observed and are of such value.

In order to try to classify this diversity it is useful to define a general formula for a lipid. A suitable one might be:



In this representation R represents the hydrophobic entity and P the more polar entity. There are in general n hydrophobic species attached m polar species. Where n is greater than 1. It is not a necessary requirement that $R_1=R_2=R_3$, a similar consideration applies for P and m. There is no implication of stereochemistry in this formula and this is, of course, another source of the diversity of lipid functionality.

In the simplest case of a fatty acid $n=1$ and $m=1$, even here there is enormous variation possible in R. In the important case of a tryglyceride P remains fixed but the number of possible combinations of R is very great. Variations in R_1 , R_2 and R_3 result in variations in melting temperatures of solids and in the general case where R contains sufficient carbon atoms to give alkyl chain flexibility a number of crystal habits are possible. Examples of the effects of changes in R on melting point and crystal habit are given in Table IV.

Table IV
Melting points of various crystal habits of triglycerides. Melting points are given in degrees Celsius. Data from Ref. 4

TRIACYLGLYCEROL	α	β_1	β_2	β
Tricaprin	-15.0			31.5
Trilaurin	15.0			46.5
Trimyristin	33.0	54.5		57.0
Tripalmitin	45.0	63.5		65.5
Tristearin	54.5	70.0		72.0
2-Lauroyldidecanoin	6.0	37.5	34.0	
2-Myristyldilaurin	24.0	48.0	44.0	
2-Palmitoyldimyristin	38.0	58.5	55.0	
2-Stearoyldipalmitin	49.0	68.0	65.0	
Triolein	-32.0	-12.0	49.0	
Trielaidin	15.5	37.0	42.0	
Trierucin	6.0	17.0	30.0	

In most commercially available fats and oils there is a range of R_n . Examples of these are shown in chart 1 and illustrate the diversity of properties that will be available from different fats and oils. It is important to realise that the useful functionalities such as mouth feel derive not the presence of a single compound but from the variety of chemical and physical properties present. These will control such features as the solid liquid ratio at room temperature and the subsequent changes on exposure to body temperature in the mouth. Thus in this and many other cases, such a spreadability, important functionality comes from the mixture of materials present.

When R contains some chemical functionality that confers stiffness on the chain stereochemical effects start to become important. These can effect

the packing of the chains and also will effect the chemical reactivity of the lipid. An example of this can be seen in the unsaturated chains. Cis-trans isomerism is very important in determining the nutritional value of lipids and the presence of double bonds in the alkyl chain restricts the ability to fit into membrane structures and increases fluidity. The interactions of macromolecules with the lipid may also be affected by the nature of R. The degree of stiffness of R and the nature of the chemical entity causing the stiffness will determine the restrictions on the interactions and in the some circumstances can give rise to highly stereospecific recognition.

The nature of the polar group is of vital importance in the interaction of the lipid with water: highly polar or charged groups will tend to be hydrophilic in nature and thus will tend to orient towards water whilst the hydrophobic groups will tend to orient towards non polar regions. These competing effects give rise to the surface activity that is often observed in lipids and to the formation of complex structures such as micelles and bilayers such as occur in membranes. Further complex liquid crystalline structures may also be formed giving rise to yet another range of diversity.

THE LITERATURE

It is not surprising that given the importance of fats and oils that there is a vast literature covering both the academic and commercial aspects of the subject.

The range of periodicals alone is enormous. Table V gives a partial list of some the periodicals dealing with lipid and lipid related research.

It is clear from the list that lipids and their wide variety of functions impinge on almost all aspects of human life and that importance of lipids at the national level is reflected by the number of national periodicals covering particular aspects of lipid science and technology.

CONCLUSIONS

Fats and oils are commercially and scientifically of great importance. In the following volume of *Grasas y Aceites* we review some of the functional properties of fats and oils. As must be clear from the foregoing any such review must be incomplete and partial. Nevertheless the editorial group hopes that this special edition of the Journal will provide a useful and up to date reference volume of current thinking and applications in the areas selected.

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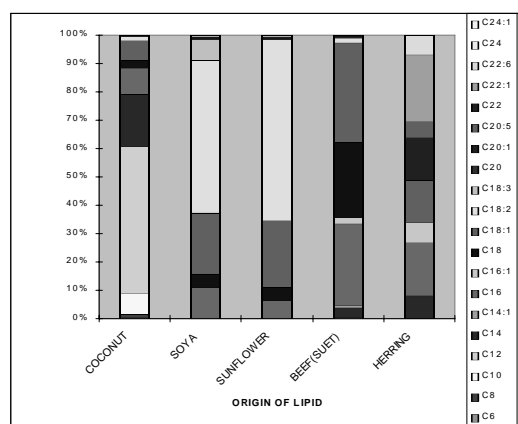


Chart 1

The variation in fatty acid content of lipids from various sources

Table V
A list of periodicals dealing with lipid research

Advances in Applied Lipid Research	Indian Journal of Dairy Science
Advances in Lipid Methodology	International Association of Food Industry Suppliers. Reporter
Agribusiness Dairyman	International Dairy Federation. Bulletin
American Oil Chemists' Society. Journal	International Dairy Federation. Catalogue of I D F Publications
Aromes, Ingredients, Additifs	International Dairy Federation. International Standard
Australia. Bureau of Statistics. Dairying and Dairy Products,	International Dairy Journal
Australian Bureau of Agricultural and Resource Economics. Australian	International Food Abstracts. Dairy Disk
Australian Dairy Foods; Production - Processing - Packaging - Marketing	International Food Ingredients
Australian Bureau of Agricultural and Resource Economics. Australian Commodity	International Journal of Dairy Technology
Statistics (Year)	
Australian Dairy Farmer	Ireland. Department of Agriculture and Food. Root Fodder Crop, Pulse and Oilseed Varieties
	Recommended List (Year)
Australian Dairy Foods	Jacobsen's Fats & Oils Bulletin
Australian Journal of Dairy Technology	Journal of Dairy Research
Ayrshire Dairyman	Journal of Dairy Science
B C Dairy Directory	Journal of Dairying, Foods & Home Sciences
Biochimica et Biophysica Acta - Molecular and Cell Biology of Lipids	Journal of Essential Oil Research
Bulletin of the International Dairy Federation	Journal of Food Lipids
Business Ratio Plus: Dairy Industry	Journal of Lipid Mediators and Cell Signalling
C A Selects. Fats & Oils	Journal of Lipid Research
C A Selects. Omega-3 Fatty Acids & Fish Oil	Journal of Oil Palm Research
California Dairy Information Bulletin	Journal of the American Oil Chemists Society
California. Agricultural Statistics Service. Dairy Industry Statistics	Journal of the Japanese Oil Chemists Society
Canada. Statistics Canada. Dairy Review	Kansanka Shisitsu Kenkyu Parallel Title: Lipid Peroxide and Research
Canada. Statistics Canada. Food Industries	Kautschuk Gummi Kunststoffe
Canada. Statistics Canada. Oils and Fats	Key Note Market Report: Milk & Dairy Products
Cereals and Oilseeds Review	Korean Journal of Dairy Science
Cheese Market News	Legume, root, oilseed and fibre crops
Chemistry and Physics of Lipids	Lipid
China Feed, Grain and Oilseed	Lipid File
China Oils and Fats	Lipid Protein Interactions
Congress of the International Society for the Study of Fatty Acids and Lipids	Lipid Review
Cream Separator and Dairy Newsletter	Lipid Technology
Current Industrial Reports: Fats and Oils. Oilseed Crushings	Lipid Technology Newsletter
Current Opinion in Lipidology	Lipids
D A I S Y - The Dairy Information System	Market Leaders in the World Dairy Industry
D M Z - Lebensmittelindustrie und Milchwirtschaft; magazine for food and dairy industry	National Dairy Council. Quarterly Review
Dairy - Deli - Bake Digest	National Dairy Research Institute. Annual Report
Dairy and Field Crop Digest	National Oilseed Processors Association. Yearbook and Trading Rules
Dairy Council Digest; an interpretive review of recent nutrition	Netherlands. Centraal Bureau voor de Statistiek. Productie Statistiek van de Zuivelindustrie
	Parallel Title: Netherlands. Central Bureau of Statistics. Production Statistics of the Dairy
	Industry
Dairy Executive	New York State Dairy Statistics
Dairy Facts and Figures	New Zealand Dairy Board. Annual Report and Statement of Accounts
Dairy Farmer	New Zealand Dairy Exporter
Dairy Field; the how-to magazine for dairy processor growth	Nigerian Journal of Palms and Oil Seeds
Dairy Foods Industry Guide	Nordic Lipid Symposium
Dairy Foods Market Directory	Nyugikyo Shiryō Parallel Title: Japan Dairy Technical Association. Bulletin
Dairy Foods Newsletter	O C L; (Oleagineux Corps gras Lipides)
Dairy Foods; innovative ideas and technologies for dairy processors	Oil World Weekly; the weekly forecasting and information service for oilseeds, oilmeals, oils and fats

- Dairy Goat Journal
 Dairy Goat Society of Australia. Victorian Branch Newsletter
 Dairy Guide
 Dairy India Yearbook
 Dairy Industries International
 Dairy Industry Bulletin
 Dairy Industry Leader
 Dairy Mail
 Dairy Market News
 Dairy Market Statistics: Annual Summary
 Dairy Markets Weekly
 Dairy Monthly Imports
 Dairy Moves
 Dairy News
 Dairy Policy
 Dairy Producer
 Dairy Products
 Dairy Products: A World Survey
 Dairy Products: The International Market
- Dairy R & D News
 Dairy Roundup
 Dairy Science Abstracts
 Dairy Today
 Dairy World
 Dairy, Food and Environmental Sanitation
 Dairy: Latin American Industrial Report
 Dairyfarming Annual
 Dairyman's Digest
 Dairyman's League News
 Department of Statistics. Cocoa, Coconut and Tea Statistics Handbook, Malaysia
 Drugs affecting lipid metabolism
 Egyptian Journal of Dairy Science
 European Dairy Magazine
 European Journal of Lipid Science
 Field Crop Abstracts; monthly abstract journal on world annual cereal,
 Finnish Journal of Dairy Science
 Food Ingredients & Analysis International
 Grain and Oilseeds
 Grains Research and Development Corporation. Annual Report
 Grasas y Aceites
 Handbook of Lipid Research
 Hoard's Dairyman; the national dairy farm magazine
 Hormone Research
 I D D A Wrap-Up
 I N F O R M: International News on Fats, Oils & Related Materials
 Indian Dairyman
- Oils & Fats International
 Oils and Fats International Directory
 Oils and Fats: The International Market
 Oils and Oilseeds Journal (also daily bulletin)
 Oilseeds and Industrial Crops
 Oilseeds, oilmeals, oils and fats
 Oily Press - book series
 Omega 3 and 6 News Online
 Ontario Dairy Farmer Magazine
 Ontario. Ministry of Agriculture, Food and Rural Analysis. Monthly Dairy
 Palm Oil Developments
 Palm Oil Technical Bulletin
 PORIM Technology
 Progress in Lipid Research
 Progress in Protein - Lipid Interactions
 Prostaglandins and Other Lipid Mediators
 Prostaglandins, Leukotrienes and Essential Fatty Acids
 Queensland Dairyfarmer
 Rakuno Gakuen Daigaku Kiyo. Shizen Kagaku Hen Parallel Title: Rakuno Gakuen University.
 Journal: Natural Science
 Retinoids and Lipid-Soluble Vitamins in Clinical Practice
 S D I - Scandinavian Dairy Information
 S W Dairy Farmer
 Seifen Oele Fette Wachse
 Shishitsu Seikagaku Kenkyu Parallel Title: Japanese Conference on the Biochemistry of Lipids
 South Africa. Milk Board. Annual Report
 Soya & Oilseed Bluebook
 Sugar, Food Product, Vegetable Oils, Wheat Product, Fats, Soaps
 Teagasc Research Report
 Telhan Patrika Parallel Title: Oilseeds Journal
 The Complete Fat Unit Guide
 The Market for Dairy Products in South East Asia
 The Western Dairyman
 Tochigi Prefectural Dairy Experimental Institute. Bulletin
 Tropical Agriculture
 Weekly Insiders Dairy & Egg Letter
 World Congress of the International Society for Fat Research (ISF).
 World Market for Dairy Products
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 Yukagaku Parallel Title: Journal of the Japan Oil Chemists' Society
 Zhongguo Rupin Gongye Parallel Title: China Dairy Industry
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