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Developments in Food Proteins – 7

Edited by

B. J. F. HUDSON

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DEVELOPMENTS IN FOOD PROTEINS—7

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DEVELOPMENTS IN FOOD PROTEINS—7

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Volume 6

PREFACE

In the previous six volumes of this series an attempt has been made to present, in each volume, a range of new topics concerned in one way or another with food proteins. This policy is continued in the present volume; six of the seven topics being reviewed for the first time.

New or developing sources of food proteins have been included regularly. In previous volumes nearly all the important grain and oilseed proteins have been discussed. However, two new ones, treated here in Chapters 1 and 2 are now emerging. Safflower seed, now ranking as a major oilseed, yields by-product protein which is becoming a significant food component. Protein from temperate zone grain legumes—peas and fababeans—is another emerging food component with considerable potential.

Of the more speculative protein sources, algae particularly warrant attention. This topic was discussed in *Developments in Food Protein—1* (1982) but it is not necessary to apologise for its revival here in Chapter 3 because important developments have taken place since that time.

Protein functionality continues to dominate a high proportion of food protein research and development studies, and already features *inter alia* in Chapters 1 and 2. In the meat industry, blood is one of the most important by-products. Consideration of its functionality, which is ultimately related to its chemical composition, determines its use in a wide range of food outlets. This is the theme of Chapter 4. Similarly, the growing interest in the West in fermented foods based on soyabeans (soybeans), for a long time popular in the East, not only demands an outline of product opportunities available to the food manufacturer but also documentation of functional properties *after*, as distinct from *before* fermentation. This new (to Westerners) protein area is the subject of Chapter 5.

Fermentation is a classical method of food preservation, probably predating drying, canning and refrigeration, although it differs from these in not only enhancing shelf-life but in inducing major chemical changes. However, there is another and new method of preservation which so far is thought to keep chemical composition substantially intact—that is, irradiation with X- or γ-rays. How do food proteins respond to irradiation? This important issue is the subject of Chapter 6. It is particularly timely in view of the current controversy concerning its safety and acceptability.

If we are to understand the behaviour of proteins in foods we must consider systematically the effects of their interaction with other components of the system. These may be either chemical or physical, obvious or subtle, desirable or undesirable. Proteins incorporate a wide range of functional groups and very complex conformational structures. It is therefore not surprising that they can interact with most other food components. Of the many types of interactions the first to be considered are those with other proteins, especially in fabricated foods with two or more distinctive protein components of diverse origins, and this is the subject of Chapter 7.

My sincere thanks are due to the eleven authors who have contributed such stimulating material for this volume and to the publishers for their support and encouragement.

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CONTENTS

Chapter 1

SAFFLOWER PROTEINS FOR FOOD USE

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SUMMARY

Safflower ranks at a low level of world production among the major oilseeds, but its availability is now increasing in various countries due to the remarkable performance of new varieties and hybrids. The proteins in the meal have an adequate balance of essential amino acids, lysine being the first limiting amino acid. However, the seed contains phenolic glucosides which are associated with a bitter taste and cathartic activity. The total seed proteins mainly consist of two fractions: 65% *with a high molecular weight* (260 000–290 000), *and* 26% *with a low molecular weight* (14 000–19 000). *Procedures have been developed for the extraction of protein isolates with bland flavors and light colors, which are important sensory characteristics for most food applications. These isolates have high water solubility, and acceptable oil binding, whipping and emulsification properties. They may be used as major ingredients in food products.*

INTRODUCTION

Safflower (*Carthamus tinctorius* L.), although one of the world's oldest crops, has become a significant world-traded oilseed only in the past 30 years. The safflower plant and name have their origin in the Near East. The earliest interest in the safflower plant was focused on its colorful florets. The orange dye of the florets, carthamine, was used in fabric coloring, as well as food coloring, in place of saffron.[1] The plant has long been domesticated, initially for the orange dye obtained from the florets, and has been positively identified as growing in Egypt 4000 years ago, probably being introduced from the Euphrates region. Its use as an oilseed crop came much later.[2]

The western expansion of the Arabs in creating the Muslim Empire of the fifth and sixth centuries AD probably helped the cultivation of safflower along the Marghreb and into Europe via the Iberian peninsula. Introduced into Britain in 1551, safflower was grown by monks and in private herb gardens. Its main use was as a food coloring, but it was also used as a dye.[3] Safflower has been used as a source of dye from ancient times by carpet weavers of the Iran–Afghanistan area, and was probably introduced into southern regions of Russia from this area. In India and Afghanistan it has been used mainly as an edible oil, but the florets are added to rice, bread and pickles to give them an attractive orange color. Around AD 200–300 safflower was introduced into China where it was used mainly as a dye and to a minor extent in medicine.

It was also introduced to North, Central and South America by Spanish immigrants during the seventeenth century. However, commercial cultivation of this oilseed crop on a large scale started only after the 1950s.[4,5] Although several abortive attempts were made to develop commercial supplies prior to 1948, successful development of the crop started when production began in California, where there was a good environment for the crop and strong support from a few oilseed processors. Commercial cultivation started in Mexico and Argentina around 1960. The subsequent growth in annual production was based on the development of improved disease-resistant high-oil varieties, improved agronomic practices and reduced shattering of ripe seed, the development of industrial uses for the oil through technological research, and increasing export markets for the seed. The growth of awareness of the relationship of cholesterol to heart disease, and in turn, the encouragement towards high polyunsaturate diets to reduce serum cholesterol, has swelled production of safflower oil as the polyunsaturated oil par excellence (80% linoleic acid).[6]

World production of safflower has increased progressively with the growth in total world consumption of vegetable oils. In 1970 seed and oil production were approximately 0·6 and 0·2 million t respectively (Table 1). By 1985 these volumes had doubled. The amount of

TABLE 1
ESTIMATED WORLD PRODUCTION OF MAJOR OILSEEDS (MILLION TONNES)[7]

Source	*1970*			*1980*			*1985*		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
Cottonseed	21·0	2·6	7·6	24·0	3·0	8·7	25·5	3·2	9·2
Linseed	4·0	1·0	1·8	3·0	1·0	1·4	3·5	0·9	1·6
Palm kernel	1·0	0·4	0·5	1·5	0·7	0·7	1·5	0·7	0·7
Peanut	15·5	2·7	3·3	16·7	3·0	3·5	16·7	2·9	3·6
Rapeseed	7·0	2·4	3·7	11·3	3·8	5·9	12·0	4·1	6·3
Safflower	0·6	0·2	0·4	1·0	0·3	0·6	1·2	0·4	0·7
Sesame	2·0	0·7	0·7	2·0	0·7	0·7	2·3	0·8	0·9
Soybean	46·0	7·0	31·8	86·0	13·0	59·5	100.8	15·3	69·8
Sunflower	10·0	3·6	3·4	14·4	5·2	5·0	19·0	6·9	6·5
World total	110·0			162·0			185·0		

A = Oilseed; B = vegetable oil; C = protein meal.

defatted meal produced annually is reported to be 0·7 million t and it is estimated that it will grow substantially in importance in the near future.[7] This by-product has been viewed as a potential source of vegetable protein for human consumption. The outstanding food properties of these proteins (e.g. bland flavor, light color, high nutritional value) offer new opportunities for greater exploitation of an under-utilized protein resource.

GENERAL DESCRIPTION OF SAFFLOWER CULTIVARS

The safflower plant is a member of the *Compositae* family, which includes sunflower, artichoke, chrysanthemum and thistle. There are some 25 valid species in the genus, distributed from Spain across North Africa and Western Asia to India; many being indigenous to the Mediterranean region. Modern assessment considers that on the basis of closely-related wild species, the probable origin of cultivated safflower is an area bounded by the eastern Mediterranean and the Persian Gulf.[8]

Basically, safflower is a dry land crop which grows best in arid climates on land with a high water table. In areas of high atmospheric humidity, such as those in the soybean belt, safflower is quite susceptible to plant diseases and therefore is not grown east of the 100th meridian.[1] However, highest yields are obtained by careful irrigation. Too much water results in root rot. An increasing portion of the crop is grown on dry land with some form of irrigation.

Safflower is a highly branched, herbaceous, thistle-like annual, with a strong central branch stem, a varying number of branches and a taproot system. The taproot can penetrate to depths of 2·4–3·0 m if subsoil temperature and moisture permit. As a result this crop is more drought-tolerant than small grains.[9] Development of safflower from planting to maturity and a comparison of the various growth periods from a number of countries, not necessarily with indigenous varieties, are shown in Table 2. Following emergence, the stem apex produces a rosette of leaves on the soil surface, which rapidly develops into a true stem. In contrast to its relatively slow start, safflower grows rapidly after the stem begins to elongate. The stem is stiff, cylindrical, fairly thick at the base, becoming thinner as branching increases, quite smooth, glabrous and light grey or green to white, with fine longitudinal grooves and becoming brittle when mature. The central stem branches from 15–20 cm to form secondary stems, which themselves branch; each branch terminating in a flower head. Each branch will usually have from one to five flower heads containing 15–20 seeds per head.

Time to flowering in a variety is basically genetically controlled, but the actual period can be greatly influenced by environment.[10] After seeding, flowering may extend over 82–100 days (Table 2). Safflower is self- not wind-pollinated, but bees or other insects are generally

TABLE 2
GENERAL CHARACTERISTICS OF SAFFLOWER CULTIVARS IN SELECTED COUNTRIES[2,5,6]

Traits	*Argentina*	*India*	*México*	*USA*[a]
Seedling emergence (days)	7–15	7–20	7–20	7 – 21
Time to elongation (days)	30	30	32	28 (121)
Branching (first order)	40	—	55	55 (150)
Flowering (days)	85–95	85–100	82–95	85–90 (185)
Plant height (m)	1·2–1·5	—	1·3–1·5	1·2–1·4
Time to harvest (days)	130	135	145–160	110–140 (220)
Grain yield (t/ha)[b]	2·0	1·5	1·6	2·2

[a] Values in parentheses represent Autumn-sown cultivars.
[b] Average values in irrigated areas.

beneficial for optimum fertilization and maximum yields. Height is a varietal characteristic; commercial varieties can vary from 1·2–1·5 m. Harvesting takes place when the plant is quite dry but not brittle; the bracts on the heads turn brown and the moisture content of seeds varies from 5 to 9%. Safflower needs harvesting from 110 to 160 days. Yields in irrigated areas average 1·5–2·2 t/ha. On rain-fed areas, yields are in the range of 0·4–1·4 t/ha.[2,6]

SEED PROPERTIES AND OIL EXTRACTION

Seed

The 'seed' of the safflower is called an 'achene' by botanists. It is defined as a small, dry, indehiscent, one-seeded fruit developed from a simple ovary and usually having a thin pericarp attached to the seed at only one point.[11] The achene resembles a small, slightly rectangular sunflower seed, but with a thicker, more fibrous hull (Fig. 1). It consists of a seed embryo (often called the 'kernel' or 'dehulled seed') and adhering pericarp ('hull'). The seed coat (testa) is generally cream

FIG. 1. General appearance of safflower seeds.

or off-white, but grey and mottled types occur. The seed coat, which comprises some 15% of the hull, consists of two epidermal layers of a brown color. A black or brown testa invariably indicates crossing with a wild species. Striped testae have resulted from crosses to produce thin-hulled seed. Brown-striped seeds have a greatly reduced hull percentage and increased oil and protein percentages, but have a definite musty odor.[12] Achene size is a varietal characteristic and is affected by environmental conditions.[2,13] Achenes from the Gila variety grown in Mexico vary in length from 6·3 to 7·4 mm, and in width from 3·2 to 4 mm; weight per 100 seeds and test weight average 11·1 g and 44·3 kg/hl, respectively (Table 3).[14]

Removal of Hulls

The average % seed composition of white-hulled commercial types is in the range of: hull, 35–45; kernel, 55–65; oil, 35–45. Oil content has risen and hull content fallen in the latest commercial hybrids and varieties. The high proportion of hull is notable, and has been a handicap to commercial production since it reduces both the seed oil percentage and the protein content of meal. Mechanical dehulling of these seeds results in broken and pulverized hulls and kernels which are separated by sieving and pneumatic procedures (Fig. 2). Fine hull particles contribute a brownish appearance to the meal and are difficult to screen from the flour. Thus, a meal with a light color is only obtained if most of the hulls have been removed before oil extraction. However, for economic reasons only partial decortication is done in the processing plants in order to increase plant throughput, decrease the transfer of hull waxes into the oil, and enhance the value of the meal.

The seeds are cleaned of foreign material ('dockage') and are separated into large, medium and small sizes. The best recovery of

TABLE 3
PHYSICAL PROPERTIES OF SEEDS[14]

Property[a]	*Level*
Seed length (mm)	6·3–7·4
Seed width (mm)	3·2–4·0
100 seed weight (g)	11·1
Test weight (kg/hl)	44·3

[a] Gila variety.

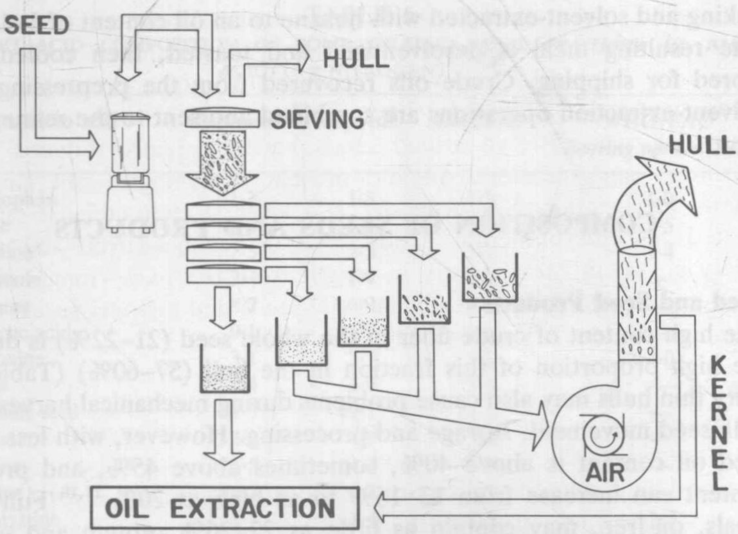

FIG. 2. Dehulling system for safflower seeds.[14]

undamaged kernels occurs when dehulling is done at 8–10% moisture. The dehulling system for safflowers utilizes a centrifugal impact dehuller to decorticate the seed, and this is followed by screening and aspiration to separate hulls from kernels (Fig. 2). Kernels are then inspected visually and stored in clean, dry areas until roasted. The degree of hull removal varies widely from processor to processor, but efficient decortication equipment in modern plants can reduce the hull content to 10–12% in the kernel fraction; that is, almost as low as decorticated sunflower.[15]

Oil Extraction

For oil extraction, safflower seeds or kernels are conditioned by heating to temperatures as high as 100°C. This treatment increases oil fluidity and denatures cell membranes to improve oil removal. Most of the mills currently processing safflower use the prepress–solvent extraction method to extract oil from the seed or kernel.[1,16] In safflower's early days in the USA, mills used only the continuous screw press (expeller). Prepressing is designed to expel about 60% of available oil in a mechanically extracted form for those consumers desiring such material. The cake is then re-granulated by grinding or