of wheat flour controls, respectively (10,19). In terms of specific loaf volumes (cc/g), values of 5.4 and 4.5 were obtained when SPI and soy protein isolate were included, as compared to 6.3 for the control.

Exploratory research and development of foods incorporating SPI developed at the Western Regional Research Center has been and/or is being conducted in academic and commercial laboratories, in the U.S. and abroad. Fortification of pastas with SPI has been studied incorporating levels of 5 through 25%. Calculated protein content of pastas increased to from 16 to 27% moisture free basis. Commercial research efforts are in progress examining the functionality of SPI in various bread and beverage formulations.

Cost estimates. Recent economic pressures within the oilseed processing industry have prompted processors of safflower seed to critically examine the returns obtained from their by-products, including meal. As a result, the feasability of producing SPI is currently receiving attention by some within the U.S. Estimates on costs of producing soy protein isolates (20) serve as a general guide for production costs for SPL. Processes for preparating both protein isolates are sufficiently similar to assume that major production costs would also be somewhat similar. During the past two years, commercially available, 42% crude protein meal has ranged in price from $150-205/metric tons with an average of ca. $190 (21). Costs of producing SPI were calculated as the sum of production costs plus costs of raw materials, i.e., safflower meal. Costs of safflower meal, per pound of SPI, were calculated as follows:

Estimated cost of producing SPI is compared with estimated costs for various soy protein products (Table II).

$$\text{Costs of safflower meal} = \frac{\text{Cost of 2,204 lbs Meal}}{\text{lbs SPI in 2,204 lbs Meal}} = \frac{\$190.00}{\frac{\%\text{ protein in meal}}{100} \times \frac{\%\text{ protein recovered in SPI}}{100} \times 2{,}204 \text{ lbs}}$$

$$\frac{\%\text{ protein in SPI}}{100}$$

Estimated cost of producing SPI is compared with estimated costs for various soy protein products (Table II). On a relative basis, SPI costs are similar to those for soy protein isolate. The cost of SPI, assuming that extracted meal would be sold as a by-product, was calculated on the basis of a weight yield of 50% for SPI and a sale price for the by-product comparable to 20% crude protein meal, i.e., ca. $95/metric ton.

Those regions of the world in which significant quantities of safflower are produced and processed are encouraged to explore this crop as a source of edible protein. This is especially appropriate for those countries which consume diets deficient in protein and calories.

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Development of Grapeseed Protein

P. FANTOZZI[1] and **A.A. BETSCHART**, Western Regional Research Laboratory, SEA/ARS/USDA, Albany, CA USA

ABSTRACT

The potential for grapeseed oil and protein in regions where grape production is significant is discussed. Extraction and concentration procedures which improve the nutritional value of grapeseed protein and problems related to protein digestibility are presented.

Grapeseeds have been explored and used as a source of oil, both experimentally and by industrial processors. Information on grapeseed protein including methods of extraction and isolation, as well as nutrition value, is limited. Grapeseeds become a part of pomace, accounting for 20-26% of this residue which results from the process of winemaking (1). In the U.S. little use is made of pomace; occasionally it has been used as a soil conditioner or source of nondigestible fiber. In Europe, however, pomace is viewed as a potentially valuable by-product. The products which may be obtained from 100 Kg of grapes are shown in Figure 1 (2,3). In addition to oil, grapeseeds represent a viable source of protein and tannins.

Grape production varies widely in various regions of the world. Production of grapes and wine by major regions with estimated production of seeds, protein, and oil are shown in Table I (4). Grapeseeds account for an average of 2.5% of the grape with values ranging from 2.2 to 6.3%. This variability is attributed to differences in variety and maturity of the grape. Europe produces nearly 60% of the world's grapes and is responsible for almost 70% of the world wine production. In addition to Europe, sizable

[1]Visiting Scientist, WRRC, SEA, USDA. Present address: Instituto di Scienza e Tecnologie Alimentari e della Nutrizione, Universita degli Studi di Perugia, Italy.

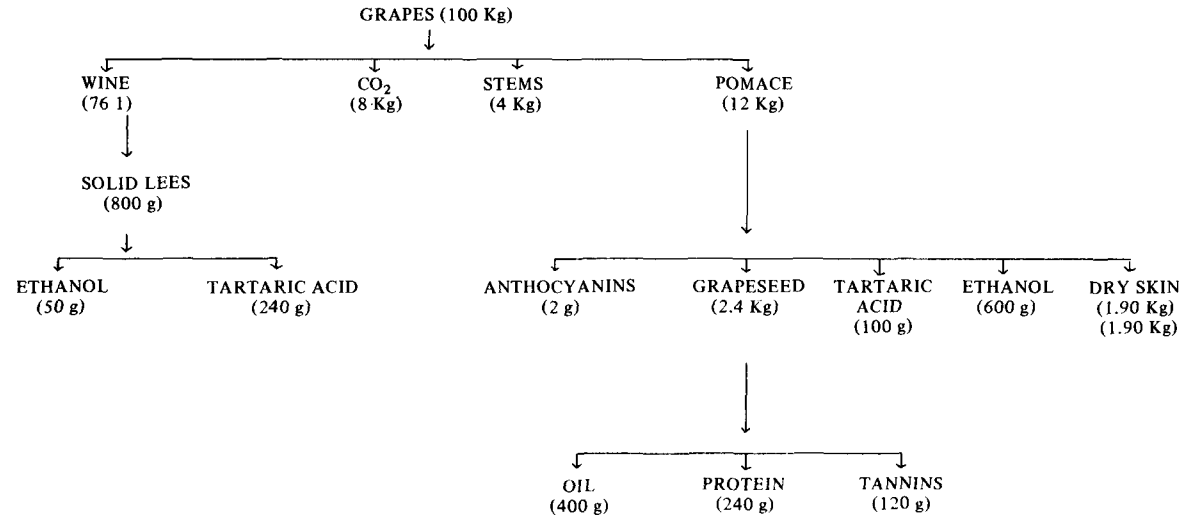


FIG. 1. Distribution of products available from grapes.

TABLE I

World Production of Grapes and Wine with Potential Production of Grapeseed, Grapeseed Protein and Oil (1,000 MT)

Area	Grape	Wine	Grapeseed[a]	Protein total	Protein yield	Oil total	Oil yield
World	59,024	30,746	1,416	155.7	77.8	240.7	192.6
Europe	34,475	21,045	827	91.0	45.5	140.6	112.5
Asia	6,187	197	148	16.3	8.1	25.2	20.2
South America	5,535	3,261	133	14.6	7.3	22.6	18.1
North and Central America	3,914	1,509	94	10.3	5.1	16.0	12.8
Africa	2,506	1,369	60	6.6	3.3	10.2	8.2

[a]Estimates calculated on the basis of grape production, composition and yield of protein and oil.

TABLE II

Composition of Grapeseed and Distribution of Constituents within Select Fractions

Distribution Grapeseed fractions	Weight	Total polyphenols % moisture free basis	Protein[a]	Crude fat
Whole seed	100	100	100	100
Endosperm	25-35	7	94	98
Internal epiderm	50-65	67	2	1
External epiderm	10-15	26	4	1

Composition *Whole grapeseed*	Range of values % weight as is
Moisture	9-11
Protein[a]	10-12
Crude Fat	16-18
Crude Fiber	39-44
Ash	2-3
Total polyphenols	5-10

[a]Protein = nitrogen x 6.25.

quantities of grapeseed and its by-products are also available in countries such as Argentina, Chile, Iran, and Turkey.

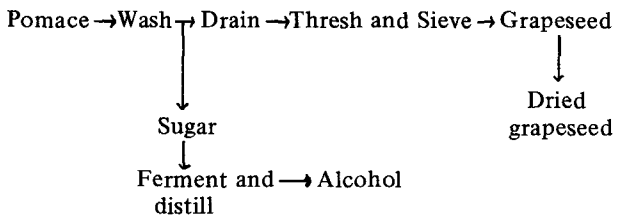
Potential production of grapeseed protein is similar to that of sunflower protein in France and Italy, and could account for 1-2% of available vegetable protein in these countries as well as Argentina. France and Italy have the most promising potential for grapeseed oil production. When compared with the major sources of oil for France, Italy and Spain, grapeseed could potentially contribute oil equivalent to 15% of France's rapeseed oil, 8% of Italy's production of olive oil, and 10% of the sunflower oil production of Spain. The impact of grapeseed oil production in the USSR and the USA would be considerably less.

Proximate analyses of whole grapeseeds show that composition lies within the range of values reported in Table II. Preliminary data on distribution of constituents within grapeseed indicate that protein and lipid are concentrated within the endosperm, whereas phenolics are located mainly in the internal and external epiderm. Thus, to obtain protein and oil from grapeseed, contents of the endeosperm should be released with minimal disruption of the stone cells and outer epiderm. The major objective would be to minimize protein-phenolic interactions.

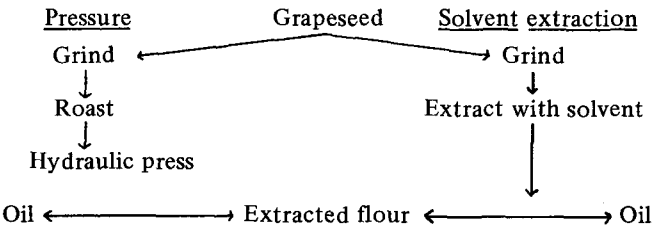
An evaluation of grapeseed protein quality on the basis of amino acid composition shows that sulfur amino acids are similar to those of soy flour, whereas lysine content of whole grapeseed protein is approximately one-half that found in soy (2,5). Grapeseed protein would be most effectively utilized when consumed in combination with other proteins having complementary amino acid patterns.

Of the several antinutritional factors present in plant food sources, including trypsin inhibitor in soy, hemagglutinins in legumes, gossypol in cottonseed and aflatoxin in peanut, it appears that phenolic constituents are of major concern in grapeseeds.

Experimentation has shown that grapeseed may be obtained from pomace by the following procedure:

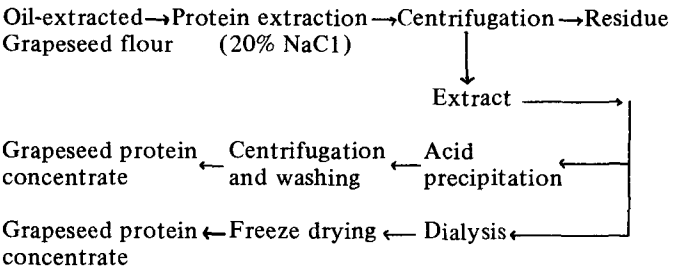


Oil may be extracted from the grapeseed by one of two methods:



The oil-extracted flour contains ca. 15% extractable protein by weight.

A procedure for protein extraction and concentration, developed by the authors (6) may be generally summarized as follows:



Whereas the technique of extracting protein from grapeseed does not present problems, protein extraction in the presence of phenolics poses the major difficulty. As shown in Table II, grapeseed contains between 5 and 10% total phenolics of which ca. 7% may be located in the endosperm, the major location site for protein. Protein-phenolic interactions and binding are well recognized and common among extracts of many plant materials (7, 8, 9). The general decrease in protein digestibility which occurs in the presence of phenolics is a continuing problem. Growth depression was observed in chicks when various fractions of phenols from grapeseed were fed (10). Formation of hydrogen bonds between phenolic hydroxyl groups and the carbonyl groups of the protein peptide bonds results in decreases in digestibility. Phenols may bind with dietary protein as well as proteolytic enzymes responsible for digestion. In addition to their influence upon nutritional value, phenolics also adversely influence color and organoleptic properties. As a result of oxidation, there is the formation of brown pigment associated with polymerization of phenols.

In vitro digestibility of grapeseed protein was assayed with pepsin-pancreatin (11). Digestiblity was evaluated on the basis of disappearance of trichloracetic acid insoluble nitrogen. In a system where casein and bovine serum albumin were 95% digestible, the digestibility of grapeseed protein was increased from 4 to 60% by altering the extraction conditions. It is apparent that extraction of grapeseed protein in the presence of NaCl, alone or in combination with Polyclar (polyvinylpyrrolidone), partially protects the protein and enhances digestibility. These and other methods which decrease or minimize protein-phenolic interactions and enhance protein digestibility should be explored. Economic and technological constraints must also be considered when evaluating such methods.

Although grapeseed appears to be a potential protein source, especially for those countries where grape production is significant and protein resources limited, minimization of phenolics in grapeseed protein products is basic to their utilization. A more definitive understanding of the interaction of protein and phenolics, as well as approaches to minimizing their interactions, would have application to various vegetable protein sources with similar problems.

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