LEGACY

The Official Newsletter of the American Amaranth Institute

Copyright, 1988 by
American Amaranth Institute
Box 216, Bricelyn, MN 56014
All rights reserved.

MAY/JUNE

Volume I — No. 1

ENDORSED BY THE INSTITUTE FOR THE DEVELOPMENT OF AMARANTH PRODUCTS, INC.

FROM THE PRESIDENT OF THE AMERICAN AMARANTH INSTITUTE

It is a privilege to have this opportunity to address you through this publication of the "LEGACY". I must accept a major portion of the responsibility for the delay of the publishing of this newsletter. The great news is " HERE WE ARE."

Thanks for all the support from the American Amaranth Institute and Institute for the Development of Amaranth Products in assisting me in this development. My special thanks to Jim Lehmann, Deb Bergsather, Marvel Prafke, Lorraine Hove, and Shirlee Jelle for their contribution of energy and assistance in making this publication a reality, and to all those individuals that have contributed editorials and advice to the American Amaranth Institute on this project.

I would also like to thank Rodale Research Center and Leon Weber for the opportunity to co-author the 1988 Amaranth Grain Production Guide as a joint venture with the Institute, and to the Jesse Smith Noyes Foundation for their assistance.

Appreciation is herein extended to Larry Walters, past president of the American Amaranth Institute. Larry's leadership in the American Amaranth Institute has helped establish the Amaranth Industry.

To you the professionals of the Amaranth Industry and interested parties, we wish to assist you in your efforts by offering research papers, editorials, and interviews with professionals of the Amaranth Industry.

I would also like to introduce you to the officers and directors of the Amaranth Institute. Each officer has a specific area of contribution that they are working on but not limited to.

President - Edward S. Hubbard -Executive Administrator ; Vice-Pres.- Wayne Applegate - Membership; Secretary - Mike Irwin - Relationships with the Organic Industry and other organizations; Treasurer - Herb Kaminky - Equipment and cooperative establishment efforts.

Directors: Leon Weber - Seed certification; Larry Walters - Certification standards and endorsements; Marvin Stumpf - Articles, By-laws and Nominations; Jim Lehmann - "LEGACY" and research.

JOIN THE AMERICAN AMARANTH INSTITUTE TODAY !!!

IN THIS ISSUE

EDITORIAL

By Elwood F. Caldwell, Ph.D., Executive Editor CEREAL FOODS WORLD

Many things may be said about amaranth. Some of them are in direct conflict with one another, such as a claim that amaranth should be regarded in the same light as a cereal grain when in fact its present and likely future cost and availability in quantity to food processors are simply out of the cereal grain ballpark. But on one thing there is reasonable agreement--- amaranth is an interesting new food ingredient.

What is the true situation? As I see it, amaranth does have much in common with the cereal grains like corn, wheat or oats. I understand that as a food raw material it can be popped, extruded, milled as a flour, or rolled into flakes for cooking. It is similar in certain analyses, is called a grain, and tends to be used as one or mixed with other grains. But I also see many differences, some of which are more critical to its future than the similarities. Like buckwheat and wild rice, it is not botanically a cereal grain, and like them, its uses are likely to be of a specialized rather than a staple nature, based on special sensory, nutritional or functional properties and, perhaps most important, cost to the processor.

The fact is that cereal grain products form some part of most processed foods. This is one reason why the American Association of Cereal Chemists has a broader membership than other societies that are commodity-oriented, and I believe accounts for the broad acceptance of our monthly magazine CEREAL FOODS WORLD by readers and advertisers. So, to grain amaranth we say "Welcome to the club" of agricultural products which food processors can consider as available to aid in the quest for new and distinctive food products. Who knows what the future will bring in such developments?

EDITORIAL

By Robert G. Hall, Extension Agronomist - Crops South Dakota State University

Two experimental lines of amaranth were grown at the South Dakota State University Brookings Agronomy Farm in the summer of 1987. One experimental line was early maturing and the other was late maturing. The plots were planted but were not harvested for yield because high winds and a moderate hail storm prevented reliable yields to be obtained. Prior to the storm in August, both experimental lines progressed favorably in growth and maturity. It would appear that the earliest maturing line would likely have matured while it is not known whether the latest maturing line would have fully matured by the end of the growing season. Presently the major problems associated with the potential of Amaranth production in South Dakota would appear to be: 1) planting equipment and 2) a reliable market source for amaranth grain which would encourage the production of the crop.

INTERVIEW WITH THE PAST PRESIDENT

Larry Walters of Naperville, Illinois, is an immediate past president of the American Amaranth Institute and is currently serving as a director on the Board of Directors of the American Amaranth Institute. Larry is Chairman of Nu-World Amaranth Inc. Naperville, Illinois. Larry has been actively involved in the food technology industry for many years. He majored in biology and chemistry and received his MS from Cleveland State University, Cleveland, Ohio, and his BS from Upper Iowa University at Fayette, Iowa. He has also attended seminars at Massachusetts Institute of Technology, Durke Training Center, Fairview, Ohio, and the Gulf Coast Marine Research Laboratory at Biloxie, Mississippi, relative to the food technology industry. He holds numerous memberships in associations associated with food technology. Larry was born in Manchester, Iowa, is married, and the father of three children.

In 1979 Larry attended an informative presentation by the Rodale Press on amaranth, and became interested and involved with amaranth grain. He said he was "intrigued by the grain's qualities" after listening to the presentation. In 1981, after doing a lot of reading and research on the grain, Larry and his brother first planted 2 1/2 acres of the amaranth grain. Now, in 1988, they are planning to plant up to 15 acres and will be focusing on hybrid seed that they are developing. They will also be planting plots of 2 1/2 acres for experimental plots using the different hybrid research seed. Through the past years Larry has been actively involved in crop research, farm machinery adaptation, and product development and marketing of the amaranth grain and finished amaranth food products.

Larry is a shareholder in Nu-World Amaranth, Inc. which processes amaranth, researches amaranth, and markets the grain in the U.S. and outside the U.S. They have developed and marketed new products such as puffed amaranth, granola, bar products, muffin, pancake, bread and speciality mixes.

Larry said the strongest point for amaranth is the "good food value or nutrition and great taste," but 'this is also the hardest point to sell to the consumer, as most people eat foods for pleasure instead of nutrition". He feels there is lots of work to do especially in sales and marketing to educate and communicate to the consumer, whether the general food industry or the individual homemaker, that when buying amaranth products you "get more nutrients for the money spent than in most other foods."

As a director of the American Amaranth Institute, Larry has had the task assignment of exploring the Food and Drug Administration's standing on amaranth. The FDA has now recognized amaranth as a "grass substance", a safe item for human consumption. He is also working with the industry to establish basic American specifications and definitions and grades of amaranth. He said, "Production has come a long way and with the existing crop research it will continue as universities and private industries and/or individuals become involved."

"The marketing should be one of 'supply and demand' with a process of balance. Hopefully, the producers will produce enough grain to meet the demand and still receive a good return on their investment, and the demand will be great enough to offer an incentive to produce and an incentive to industry to market new products."

LEGACY IS BINDER READY

The American Amaranth Institute's Newsletter has a new name, **LEGACY,** and a new layout. The "new look" is designed and punched so that the newsletters may be placed in a 3-ring binder for storage. In this way the articles and information contained in the newsletters can be used for future reference.

1988 PRODUCTION GUIDES ARE AVAILABLE

The 1988 AMARANTH GRAIN PRODUCTION GUIDE has been published and is now available from the American Amaranth Institute, Post Office Box 216, Bricelyn, MN. 56014.

The guide is co-authored by the Rodale Research Center and the American Amaranth Institute. The production guide is included with your annual membership fee of $25.00. Individual copies may be purchased for $5.00.

GLOSSARY

A hypochondriacus: 1023 species Grain Type: mercado. A standard mercado grain type line. It develops a red root, green stem, leaf and flower. It has excellent seedling vigor, and produces a large, white grain. It grows up to eight feet tall when moisture and fertility are not limiting. It is limited to areas with a long growing season, as it requires about 150 days to mature.

A cruentus: K283 species Grain Type: Mexican x African. A distinguishing marker is the red leaf margin and red leaf veins. Flowers develop varying shades of red and pink. It matures about a week earlier than 1011. Under optimum growing conditions plants grow up to six feet tall. The white grain is slightly smaller than grain of the Mexican grain type plants.

A hypochondriacus x A hybridus: K343 species Grain Type: mercado x prima. This line has a red root, green stem, and a hint of a red patch on a green leaf. At maturity the entire plant may turn red. Days to maturity are determined by the time of planting. When planted in early June at Rodale Research Center it matured a week later than 1011. However, it matured earlier than the Mexican grain type when planted in late June in western Nebraska. Several growers have noted its superior standability after a killing frost. It produces large white grain.

A hypochondriacus x A hybridus: K432 species Grain Type: Nepal x prima. The first semi-dwarf released for evaluation. It develops a large flower panicle on a four foot plant. During the first weeks of growth there is a distinctive purple patch in the center of the leaf. The purple pigment fades as the plant matures and plant becomes all green. It matures about a week before 1011 and produces large white grain.

CARBOHYDRATES OF AMARANTH

by Jim Lehmann, Iowa State University, Ames, Iowa

The granular starch of grain amaranths is found in the center of the lenticular seed. In contrast to "grass family" cereals as oats and corn, the central storage area of the seed is termed the **perisperm,** not the endosperm. The perisperm is derived from a maternal tissue called the nucellus and is genetically diploid or 2n. Corn and oat starch is formed in the triploid (3n) endosperm, which is formed during fertilization.

Amaranth is the first documented case of a broadleaf plant or dicot which has both **glutinous** and **non-glutinous** starch. Extensive studies on both the **translucent** and **opaque** perisperms showed that the former contained amylose and amylopectin while opaque contains almost entirely amylopectin. Amylose is a linear starch polymer of up to 6000 glucose molecules. Amylopectin, on the other hand, is a highly branched structure consisting of numerous short amylose chains. Japanese researchers have determined that one gene controls this starch character (Okuno & Sakaguchi, 1982).

SEE TABLE 1

An **Amaranthus hypochondriacus** seed is about 60% starch by weight (Becker et al., 1981). Starch contents in **A. cruentus** seeds range from 48% to 69%. Less than one percent of the seed is sucrose. Only trace amounts of free fructose and glucose have been found in the seed (Lorenz & Gross, 1984).

Amaranth starch granules are unusually small, only **1 to 3 microns** or micrometers **in diameter**. Contrast the oval starch granules of potato which are 100 microns in diameter. The smallest, commercially-used starch granules are those of rice (3-8 micron diameter). Typically, such small granules are most useful in food thickeners, as dusting powders in cosmetics and bread-baking pans, and in laundry starches. These tiny **polyhedral and round starch granules** were first identified over 20 years ago in redroot pigweed (**A. retroflexus** L.). The scientists who discovered similar granules in cow-cockle seed (**Saponaria vaccaria**) also patented a refining process. (D. L. Brelsford and K.J. Goering; U.S. Patent 3,622,389: Petersen. 1975).

Recently, Japanese investigators have found a starch granule-bound enzyme (synthase) to be associated with amylose synthesis in amaranth (Konishi et al., 1985). A homozygous non-waxy (WxWx) line and a hybrid (Wxwx) produced 16.9% and 10.7% amylose respectively, while the homozygous waxy (wxwx) line produced no amylose i.e., all amylopectin. Synthases, as their name implies, are biosynthetic enzymes which link glucose molecules together during starch formation. They may be found in soluble form in the cytoplasm or bound to the starch granule. In waxy maize, researchers have also found an absence of the granule bound starch synthase (Preiss & Levi, 1980). Since amylose has been shown to be capable of absorbing synthase in certain waxy rice and maize lines, its presence may be necessary for the synthase to bind to the starch granules. The amylose content of various amaranth lines ranges from 4.8 to 22% (Saunders & Becker, 1984; Tomita et al., 1981). The percentage of amylose in these non-glutinous or non-waxy lines is low compared to amylomaize (50-80% amylose) or sorghum (28% amylose). Normal corn starch is about 24-26% amylose.

Amaranth starch granules are attacked more quickly by fungal **glucoamylase**, a starch-splitting enzyme, than are the granules of cornstarch. A Japanese study determined that **normal and waxy type amaranth starch was digested from 2.4 to 5 times faster than corn starch** (Sugimoto et al., 1981). Stone & Lorenz (1984) suggest that both corn and amaranth starch are not readily attacked by alpha- amylases.

An interesting observation about **endogenous amylase** of amaranth seed was recently reported (Yanez et al., 1986): amaranth flour stored for short periods showed up to 11% starch breakdown while longer storage periods resulted in up to 18% hydrolysis. The authors point out that "in general, cereal grains do not show major activity [starch hydrolysis by endogenous enzymes] until germination." Additionally, amaranth/wheat blends also showed enhanced levels of starch hydrolysis or breakdown.

The functional

properties of amaranth resemble those of rice, probably due to the small starch granule size. Like rice, waxy amaranth starch is a poor performer in bread and cakes (Stone & Lorenz, 1984). However, the functional properties of amylose-containing amaranth lines were not studied by these authors. They note that, "the amylose content of starch affects baking performance "(Stone & Lorenz, 1984). Amaranth/flour blends have been effectively processed into enriched cookies and French bread (Sanchez-Marroquin et al., 1985). Extrusion cooking of amaranth flour has also yielded satisfactory results (Mendoza & Bressani, 1987).

Gelatinization or absorbing water and swelling at a critical temperature is well known in starches. Non-glutinous rice starch shows a higher temperature for the initiation of gelatinization than both waxy and non-waxy amaranth (Sugimoto et al., 1981). Wheat, comparatively, has about a 10 degree Celsius lower initial gelatinization temperature (Saunders & Becker, 1984). Amaranth gelatinization temperatures from 51 to 76 degrees Celsius have been reported by Japanese researchers (Tomita et al., 1981); apparently, there are significant species and varietal differences. The low gelatinization temperature of some amaranth lines may be useful in vegetable soups (Yanez et al., 1986).

Similar to waxy rice (Schoch, 1967), starch of gold-seeded **A. hypochondriacus** L. shows resistance to insolubilization by freezing. In other words, the starch remains relatively stable after repeated freezing and thawing. Yanez et al. (1986) suggest such a property would be desirable for gravies and sauces.

Fermentation of amaranth starch is poorly understood (Aidoo, 1986). An early fermentation test on redroot pigweed starch (Goering, 1967) suggests amaranth starch may be digested more rapidly and completely than cornstarch. Amaranth fermentation has also been studied in the production of Mexican tamales (Ramirez-Valazquez, 1983).

Other areas which bear on amaranth carbohydrates are milling, processing, and popping properties. These areas will be discussed in future articles.

TABLE 1 Starch and perisperm types based on **Amaranthus hypochondriacusL.**

Perisperm-type	Starch molecule(s)	Waxy or non-waxy	Genotype	Iodine Test
Translucent	Amylose + amylopectin	non-waxy, non-glutinous	WxWx	Blue-purple
Opaque	Amylopectin	waxy glutinous	wxwx	Reddish brown

AREAS FOR FURTHER STUDY

1. WET MILLING CHARACTERISTICS OF waxy and non-waxy amaranth starches. 2. SUITABILITY OF AMARANTH STARCH IN RICE-LIKE APPLICATIONS. As stated earlier, laundry starch, puddings, and cosmetics are probable areas of suitability based on small granule size. 3. DEFINE MORE COMPLETELY CHEMICAL, PHYSICAL AND FUNCTIONAL PROPERTIES of amaranth starch and develop product applications which exploit unique properties. 4. CHEMICAL MODIFICATION of amaranth starches. Depolymerization, cross-linking, cationization, and carboxymethylation could produce novel and unique properties (Fleche, 1985). 5. AMARANTH STARCH AS A CARRIER IN AEROSOL COSMETICS. An area previously suggested by Saunders and Becker (1984). 6. SUSCEPTIBILITY OF AMARANTH STARCH TO ATTACK BY VARIOUS AMYLASES AND DEBRANCHING ENZYMES like isoamylase and pullalanase. For example, various cereal, bacterial, and fungal amylases should be tested. 7. ROLE OF ENDOGENOUS AMYLASES in amaranth cereal/blends with respect to starch hydrolysis, digestibility, and fermentation, especially ethanol fermentation. 8. BIOTECHNOLOGICAL STUDY OF AMARANTH SOLUBLE AND STARCH-BOUND SYNTHASES.

COMMENTARY

Amaranth starch is a renewable resource of relatively unexplored potential compared to major cereal starches. With the recent expansion of amaranth production in the People's Republic of China and incipient production in Mexico, India, Peru, and the United States, the need for basic starch functionality and product-oriented research becomes greater. Researchers should be aware that there are probably species and varietal differences for many starch aspects. No longer should we state quantitative results for amaranths-at-large: there are over 60 species of amaranth in the world and probably 4-6000 lines of domesticated and wild amaranths in the base and regional germplasm collections.

Over 3000 research articles on amaranths are known from scientific literature. By increasing industrial, entrepreneurial, and academic awareness of these plant resources, we hope to advance North America's ancient crop toward its future niches.

AMARANTH CARBOHYDRATE LITERATURE with ANNOTATIONS

Aidoo, K.E. 1986. Lesser known fermented plant foods. Tropical Science 26:259-273. (Deals with fermented foods from unusual cereal, pulse, tuber, and tree sources.)

Becker, R., Wheeler, E.L., Lorenz, K., Stafford, A.E., Grosjean, O.K., Bethschart, A.A., and Saunders, R.M. 1981. A compositional study of amaranth grain. J. Food Science. 46: 1175-1180. (A comprehensive, chemical composition study of ten amaranth lines.)

Betschart, A.A., Irving, D.W., Shepherd, A.D., and Saunders, R.M. 1981. **Amaranthus cruentus**: milling characteristics, distribution of nutrients within seed components and the effects of temperature on nutritional quality. J. Food Sci. 46:1181-1187. (Effects of milling with a modified barley pearler were studied by histological, nutritional, and chemical methods.)

Carlsson, R. 1979. Quantity and quality of **Amaranthus** grain from plants in temperate, cold, and hot and subtropical climates - a review. Proc. First Amaranth Conference, Rodale Press, Emmaus, Pennsylvania. (Seed composition of 25 amaranth varieties covering seven species was studied.)

Fleche, G. 1985. Chemical modification and degradation of starch. In Van Beynum, G. M. A., and Roels, J.A. (ed.) Starch conversion technology. Marcel Dekker, New York. (General principles of starch modification technology.)

Goering, K.J. 1967. New starches. II. The properties of the starch chunks from **Amaranthus retroflexus**. Cereal Chemistry. 44:245-252. (Physical properties of redroot pigweed starch were studied after wet milling.)

Goering, K.J., Subba Rao, P.V., Fritts, D.H., and Carroll, T. 1970. New starches. VI. The structure of the starch chunks from **Amaranthus retroflexus**. Starke 22:217-221. (Examines redroot pigweed starch chunks by light and electrom microscopy.)

Irving, D.W., and Becker, R. Seed structure and composition of potential new crops. Food Microstructure 4:43-53. (Scanning electron and fluorescent microscopy of **A. cruentus** and **A. edulis** seeds.)

Irving, D.W., Betschart, A.A., and Saunders, R.M. 1981. Morphological studies on **Amaranthus cruentus**. J. Food Sci. 46:1170. (Scanning electron micrographs depict the endosperm, perisperm, and embryo of amaranth seeds.)

Konishi, Y., Nojima, H., Okuno, K., Asaoka, M., and Hidetsugu, F. 1985. Characteristization of starch granules from waxy, nonwaxy, and hybrid seeds of **Amaranthus hypochondriacus** L. Agric. Biol. Chem. 49(7):1965-1971. (A genetic and starch property study which reveals a putuative starch granule-bond enzyme.)

Lorenz, K. 1981. Amaranthus hypochondriacus: Characteristics of the starch and baking potential of the flour. Starch 33(5):149-153. (An unidentified A. hypochondriacus line was tested for its starch and bread-making properties.)

Lorenz, K., and M. Gross. 1984. Saccharides of amaranth. Nutritional Reports International. 29(3):721-727. (A comprehensive, saccharide analysis of three amaranth species and one hybrid.)

Mendoza, M.C., and Bressani, R. 1987. Nutritional and functional characteristics of extrusion-cooked amaranth flour. Cereal Chem. 64(4):218- 222. (A new paper from INCAP on extrusion processing of amaranths.)

McMasters, M.M., Baird, P.D., Holzapfel, M.M., and Rist, C.E. 1955. Preparation of starch from **Amaranthus cruentus** seed. Econ. Bot. 9:300-302. (An early paper on preparing amaranth starch for phagocytosis studies.)

Modi, J.D., and Kulkarni, P.R. 1976. New starches - - the properties of the starch from **Amaranthus paniculatus**. Linn. Acta Alimentaria 5:399-402. (A study of an Indian amaranth, probably a waxy **A. hypochondriacus** since the Indian germplasm collection is either **A. hypochondriacus** or **A. caudatus**.)

National Research Council. 1984. Amaranth. Modern prospects for an ancient crop. National Academy Press: Washington, D.C. (A succinct account of basic amaranth information up to 1984.)

Okuno, K. & Sakaguchi, S. 1981. Glutinous and non-glutinous starches in perisperm of grain amaranths. Cereal Res. Communications 9:305-310. (First report on the two starch types and their properties in two amaranth species.)

Okuno, K., & Sakaguchi, S. 1982. Inheritance of starch characteristics in perisperm of **Amaranthus hypochondriacus**. J. Heredity 73:467. (Basic genetics of the single gene inheritance of waxy and non-waxy starch types.)

Okuno, K., and Sakaguchi, S. 1984. Differentiation of starch property in persisperm of grain amaranths. Japanese Agricultural Research Quarterly (JARQ) 18(1):1-5. (Very similar in content to the authors' 1981 and 1982 papers.)

Petersen, N.B. 1975. Edible starches and starch-derived syrups. Food Technology Review No. 24, Noyes Data Corporation, Park Ridge, New Jersey. (A basic reference text of U.S. patent literature on starches.)

Preiss, J., and Levi, C. 1980.

Starch biosynthesis and degradation. In Biochemistry of Plants, Vol. 3, Academic Press, New York. (An exhaustive, technical review of starch biosynthesis and degradation.)

Radley, J.A. 1976. Industrial uses of starch. Applied Science Publishers, Ltd., London. (Details how small granule starches are used in cosmetics, pharmaceuticals, insect powders, and explosives.)

Ramirez-Valazquez, F. 1983. Application of the Indian idli fermentation to production of Mexican tamales and South American arepas, from corn, soybean and amaranth. M.S. thesis, Cornell Univ., Ithaca, New York. (One of the few fermentation studies on amaranth.)

Sakamoto, S. 1982. Waxy endosperm and perisperm of cereal and grain amaranth and their geographical distributions. J. Japanese of Starch Sci.29(1):41-55. (A Japanese article with English abstract on Nepalese **A.hypochondriacus** starch types.)

Sanchez-Marroquin, A., Domingo, M.V., Maya S., and Saldana, C. 1985. Amaranth flour blends and fractions for baking applications. J. Food Sci. 50:789-794.

Saunders, R. M. 1985. Comments re post-harvest processing and nutrition, and marketing. In Amaranth Newsletter, IV: Archivos Latinoamericanos de Nutricion, Guatemala City, Guatemala. (Suggests amaranth research areas; includes a list of other research priorities.)

Saunders, R.M. and Becker, R. 1984. Amaranthus: A potential food and feed resource. In "Adv. Cereal Science and Technology", Vol. 6 Pomeranz, Y. (Ed.) American Association of Cereal Chemists, St. Paul, MN. (The most comprehensive review of amaranth literature to date.)

Schoch, T.J. 1967. Properties and uses of rice starch. In Whistler, R.L. and Paschall, E.F. (ed.), Starch: chemistry and technology, Vol. II, Industrial aspects, Academic Press, New York. (A general review of rice starch.)

Stone, L.A. and Lorenz, K. 1984. The starch of **Amaranthus**--- physico- chemical properties of and functional characteristics. Starch 36:232-237. (A comparison of the starch properties of two waxy species with corn.)

Subba Rao, P.V. and Goering, K.J. 1970. New starches. V. Properties of the small starch granules from **Amaranthus retroflexus**. Cereal Chem. 47:655- 661. (Three procedures were used to prepare starch granules of redroot pigweed.)

Sugimoto, Y., Yamada, K., and Sakamoto, S. 1981. Some properties of the normal and waxy-type starches of **Amaranthus hypochondriacus** L. Starch 33:112- 116. (Both glutinous and non-glutinous starches were studied for amylase digestion and pasting characteristics.)

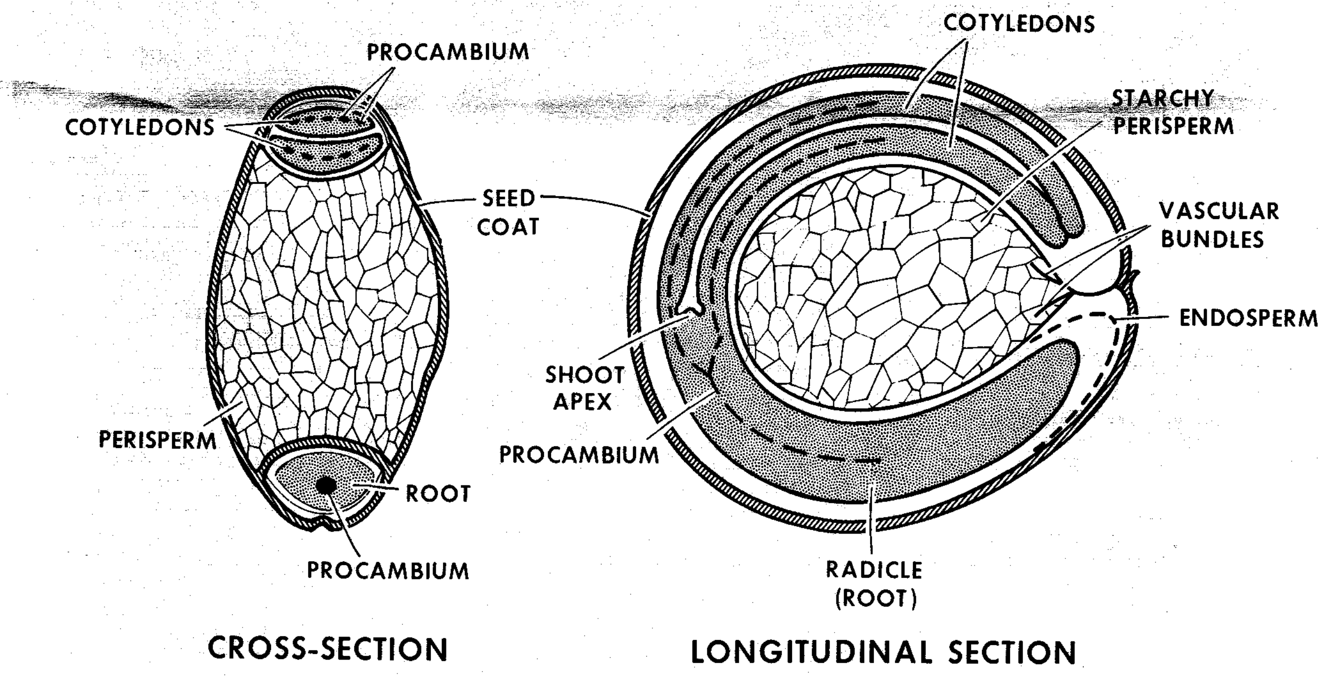
Teutonico, R. A., and Knorr, D. 1985. Amaranth: composition, properties, and applications of a rediscovered food crop. Food Technology 39(4):49-53. (A well-researched overview of amaranth vis-a-vis food technology.)

Tomita, Y., Sugimoto, U., Sakomoto, S., and Fuwa, H. 1981. Some properties of starches of grain amaranths and several millets. J. Nut. Sci. Vitaminology 27(5):471-484. (A comparison of both amaranth starch types with starch granules of proso millet, Japanese barnyard millet, and glutinous foxtail millet.)

Wolf, M.J., McMasters, M.M., and Rist, C.E. 1950. Some characteristics of the starches of three South American seeds used for food. Cereal Chem. 27:219-222. (An early report of the low gelatinization temperature and small starch granules in **A. hypochondriacus**.)

Woodcock, E.F. 1931. Seed development in **Amaranthus caudatus** L. Paper Mich. Acad. Sci Arts & Letters 15:173-178. (An early report on starch in the perisperm of amaranth.)

Yanez, G.A., Missinger, J.K., Walker, C.E. and Rupnow, J.H. 1986. **Amaranthus hypochondriacus**: starch isolation and partial characterization. Cereal Chemistry 63(3):272-276. (Details endogenous amylase activity in wheat/amaranth blends and suggests some potential food uses.)



Amaranthus cruentus. Starch from seed. Scanning electron micrograph. 13,820X