Red Food Colorant Extract Derived From Purple-Hulled Sunflower

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North Dakota State University has been conducting research on purple-hulled sunflowers, with the objective of developing a process to extract the colored pigments, anthocyanins, for use in the commercial production of natural red food colorant. This research is being carried out at NDSU in cooperation with the public and private sectors. NDSU scientists participating are from the departments of agricultural economics, agricultural engineering, cereal science and food technology, crop and weed sciences, and food and nutrition.

The production of a natural red colorant from purple-hulled sunflower is a promising new technology for North Dakota. Even though food processors still rely heavily on synthetic red colorant, and several other natural red food colorants are produced from fruits and vegetables, several factors make this venture economically and scientifically worth pursing.

First, food processors face increasing pressure to switch from traditional synthetic red colorants to natural colorants. Red Dye #2 was delisted by the Food and Drug Administration (FDA) in 1976 and Red Dye #3 was banned for use in certain products in 1989. The only remaining synthetic red colorant available for widespread use is Red #40. Red #40 is less expensive than all natural red colorants. However, even if use of Red #40 is permitted in the future, consumers increasingly perceive a natural food ingredient to be a more healthful ingredient.

Second, red colorant from purple-hulled sunflower has two major advantages over other natural red colorants. The colorant is present in sunflower hulls in a much higher concentration. For example, cranberry pomace and grape skins yield 15 to 85 mg red pigments/100 grams, respectively, while red pigment levels in sunflower hulls range up to 2,500 mg/100 grams. Also, unlike sunflower hulls, all other commercially important sources of natural red colorant are highly perishable, and are therefore not suited to year-round processing.

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Last, as an additional byproduct to conventional sunflower processing, the red colorant could improve profitability for both growers and the processor. Sunflower seed is already processed in North Dakota, and production of the red colorant would likely be integrated into such a facility. North Dakota ranks first nationally in both oil and non-oil sunflower production; thus, North Dakota is uniquely positioned to commercially produce this particular red colorant.

The main goal of the research underway at NDSU is the commercialization of red food colorant from sunflowers. Specific objectives are:

1. To quantify and characterize anthocyanin pigments
2. To develop the process for obtaining a stable, soluble extract
3. To obtain scale-up information for a commercial process
4. To develop a sunflower variety with high pigment levels
5. To analyze the market potential for this red colorant
6. To secure private industry support for a research partnership which would ultimately lead to commercialization.

SUNFLOWER ANTHOCYANIN PIGMENT CHARACTERIZATION

The pigment of purple-hulled sunflowers contains several anthocyanins. NDSU scientists have identified the two major anthocyanins in Neagra du Cluj, the genotype that has been used extensively in this research: cyanidin-3-glucoside and cyanidin-3-xyloside. Further work is needed to identify the other anthocyanin components in Neagra de Cluj and other purple-hulled genotypes. The techniques which are used include solvent extraction followed by paper, thin-layer, and high performance liquid chromatography.

Characterizing the pigment is important for evaluating the colorant's safety as a food additive. Humans have been consuming anthocyanins in fruits and vegetables (e.g., apples, grapes, blueberries, radishes, eggplant, red cabbage) for centuries; however, the Food and Drug Administration may require testing of the sunflower colorant before the colorant is allowed in foods. Identification of the anthocyanin components will likely be considered when the FDA decides what testing will be required. This will in turn determine the expense of those tests.

Characterizing anthocyanins from genotypes showing different components may also establish important relationships governing composition and differences in color, stability and other attributes of the pigment. This information would be invaluable in breeding sunflower genotypes with more and/or better pigment.

PIGMENT EXTRACTION, QUANTIFICATION, AND STABILIZATION

Quantification of anthocyanin pigments is essential for selecting high-pigment lines for commercial production. The quantity of pigments is determined spectrophotometrically, by measuring adsorption of light. The pigment content in hulls from 15 lines of sunflower ranges from 0.23-2.47 percent. For comparison, Neagra de Cluj, the cultivar which has been studied most extensively because of its availability, has 0.80 percent pigment in its hulls.

Solubility and stability are both critical to the acceptance of natural red food colorants. Obviously, a red colorant is needed which resists precipitation over time and which is not readily faded by prolonged exposure to light. A process has been developed at NDSU which yields a red colorant with acceptable solubility and stability when stored for 12 months at ambient temperature and acid pH. More than 70 percent of red food colorant is used in beverages with an acid pH.

The process of obtaining this stable colorant consists of eight steps: hull cleaning, hull grinding, sifting ground hulls, aqueous extraction, centrifugation, filtration, evaporation and spray drying. The spray drying step is optional, depending upon whether the colorant is desired in a liquid concentrate or dry, powdered form. Only food-grade processing aids are used to obtain a stable extract. Research on this process continues, in an effort to improve product quality while reducing processing costs.

SCALE UP OF THE EXTRACTION PROCESS FOR SUNFLOWER RED COLORANT

The eight-step process described for obtaining red colorant from purple-hulled sunflowers was initially developed as a laboratory batch process which produces less than 20 grams of dry powdered product per day. That quantity of pigment is adequate for shelf-life stability studies and pigment characterization; however much greater quantities of pigment will be needed to perform product application trials and anticipated FDA-mandated toxicity tests. Thus, a semi-continuous process is currently being developed which will produce over 100 grams dry powdered product per hour. This scaled-up process will be referred to as the bench-scale process. It is based on the same eight steps listed above.

The heart of this process is the extraction equipment, which was specially designed and fabricated for this process (Standard Industries, Fargo). Ground, sifted hulls from a feed hopper are metered by means of a screw conveyor to a thickener-type tank. In the tank, the ground hulls are mixed with water. The solids gradually settle to the bottom of the tank and are then continuously removed from the tank by a screw conveyor. Within this second screw conveyor, the solids come into contact with fresh water in countercurrent flow. The countercurrent operation ensures high recovery of extract from ground hulls. Addition of ground hulls and water and removal of liquid extract and solid residue is continuous. The tank is jacketed to provide temperature control.

All equipment needed for a complete process is in place, except for pressure filtration and evaporation. It is anticipated that the process will be completed by June 1991; however, the process will continue to be refined to minimize processing costs. In addition to providing larger quantities of pigment, the bench-scale process will also permit a more accurate estimate of the cost of a commercial facility, and will provide useful data for the construction of a pilot plant facility which would produce 0.5-1.0 kilograms dry product per hour.

SUNFLOWER SUPPLY AND BREEDING EFFORTS

Operation of the bench-scale process requires a significant amount of hulls. Thus far, about 2,000 pounds of hulls from Neagra de Cluj have been produced to meet this need. Plans are underway to grow sufficient sunflower to supply at least an additional 2,000 pounds of hulls in 1991. Although Neagra de Cluj is adequate for the initial process development, this genotype will probably not be used commercially.

To our knowledge, there is not currently available a sunflower genotype which has the combination of high pigment levels, high oil levels, and good agronomic characteristics that would be desirable for commercial red colorant production. Although the purple-hulled trait is controlled by a dominant gene, and several private seed companies are interested in developing purple-hulled hybrids, it could be several years before such a genotype is available.

ECONOMIC ANALYSIS

The economic feasibility of producing a natural red colorant from purple-hulled sunflower depends on its cost and return. Using preliminary investment and cost data, a model plant was simulated to operate 24 hours daily and produce an annual volume of 780,000 pounds of extract (300 days per year).

Total plant investment amounted to $5.18 million excluding working capital requirements. Annual working capital required was $1 million. Based on preliminary estimates average variable costs and average fixed costs were $1.48 and $1.26 per pound, respectively, for an average total cost of $2.74. Annual depreciation, interest on plant investment, and general and administrative overhead were the major fixed costs, while selling and marketing, raw materials, and labor were the major variable costs (Table 1).

Based on comparable tinctorial strength with other natural red colorants, sunflower anthocyanin could carry an estimated market price between $4 and $6 per pound of extract. In calculating potential return on the project, prices of $4, $5, and $6 were used to represent a low, medium, and high price.

The method used to calculate profitability of this project was the internal rate of return (IRR). IRR is usually thought of as the rate of return the project earns during its planning horizon. A 15-year planning horizon was assumed for this project because technological changes may result in the equipment becoming obsolete. An advantage of the IRR methodology is that it takes the time value of money into consideration. The IRR for this project ranged from 17 percent for the low price level to 34 and 49 percent for the medium and high price levels.

Table 1. Estimated annual variable and fixed costs for a commercial anthocyanin plant, North Dakota, 1990.

Item	Cost
Variable Costs	
Selling and marketing	$390,000
Raw material	312,000
Labor	212,400
Fringe benefits	63,720
Repairs and maintenance	88,500
Natural gas	60,000
Electricity	21,600
Water	5,580
Product liability insurance	1,365
Total variable costs	$1,155,165
Average variable costs (per pound) - $1.48	
Fixed Costs	
Annual depreciation	$284,160
General and administrative overhead	257,000
Interest on plant investment	265,162
Interest on net working capital	99,743
Property insurance	47,060
Property taxes	8,520
Building maintenance	22,200
Total fixed costs	$983,602
Averaged fixed costs (per pound) - 1.26	
Total costs	**$2,138,767**
Average total costs (per pound extract) - **$2.74**	

CONCLUSION

Interest in the natural red food colorant from purple-hulled sunflowers is very high at NDSU. However, it is tempered with the realization that commercialization is still several years away. Sunflower cultivars with high pigment levels combined with good oil levels and good agronomic characteristics are needed, and the safe use of the colorant in foods must be established to the satisfaction of FDA. Meanwhile, researchers at NDSU will continue to improve methods for characterizing, stabilizing, and processing the colorant, particularly with hulls containing higher concentrations of pigments.

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