Producing Omega-3 Polyunsaturated Fatty Acids and Chitin/Lactic Acid from Cull Potatoes

Zhiyou Wen, Yan Liu, Craig Frear, and Shulin Chen
Department of Biological Systems Engineering, Washington State University, Pullman

ABSTRACT:

Using cull potatoes to produce nutraceuticals such as ω-3 polyunsaturated fatty acids (ω-3 PUFAs), and chitin/lactic acid provides a new way to produce these chemicals and reduce the cost of feedstock used during the fermentation process. ω-3 PUFAs have beneficial effects in treating and preventing Alzheimers disease or heart diseases, while chitin/lactic acid has a variety of medical and food applications. Research conducted by our group has shown that potato starch is an ideal carbon source for algae to produce ω-3 PUFAs; and for the fungi to produce chitin/lactic acid. Compared with the high cost of pure sugars conventionally used, the presented production process could significantly reduce the medium cost while produce ω-3 PUFAs and chitin/lactic acid at comparable levels. This process could provide an opportunity for local farmers and rural communities to develop a cost-effective process for utilization of cull potatoes. If such processing facilities are developed within the state, our farmers could become not just commodity exporters but value-added processors as well.

CULL POTATOES IN WASHINGTON STATE:

It is estimated that there were 159,000 acres of potatoes in Washington in 2004. The yield harvested per acre was around 29.5 tons (590 CWT). Accordingly, the whole state produced 4.69 million tons (93.8 million CWT) of potatoes last year. For every acre of potatoes harvested, 10-15% of the crop is graded culls. This includes undersized tubers, bruised, damaged, and deformed tubers, and tubers unfit for market. If taking 10% of cull rate, the whole state produced 0.47 million tons of cull potatoes.

Currently, cull potatoes are mainly used as animal feed, with the sale price between $15/ton to $45/ton, some time the price could hit as high as $60/ton. On the other hand, fresh cull potato, with its rich composition in starch and nutrients, can be an ideal raw material for microorganisms to produce value-added products. In the next section, two cases of producing value-added products from cull potato by microorganism fermentation are presented.

PRODUCING VALUE-ADDED PRODUCTS FROM CULL POTATOES:

Fresh cull potatoes contain ~15% of starch, ~2% proteins and some other nutrients such as trace elements and vitamins. Starch can serve as carbon source for organism growth, while protein and other elements/vitamins can serve as nitrogen, phosphorus, and other minor nutrients. Through a fermentation process, microorganisms produce value-added products such as w-3 PUFAs or chitin/lactic acid. Above process is shown in Figure 1.

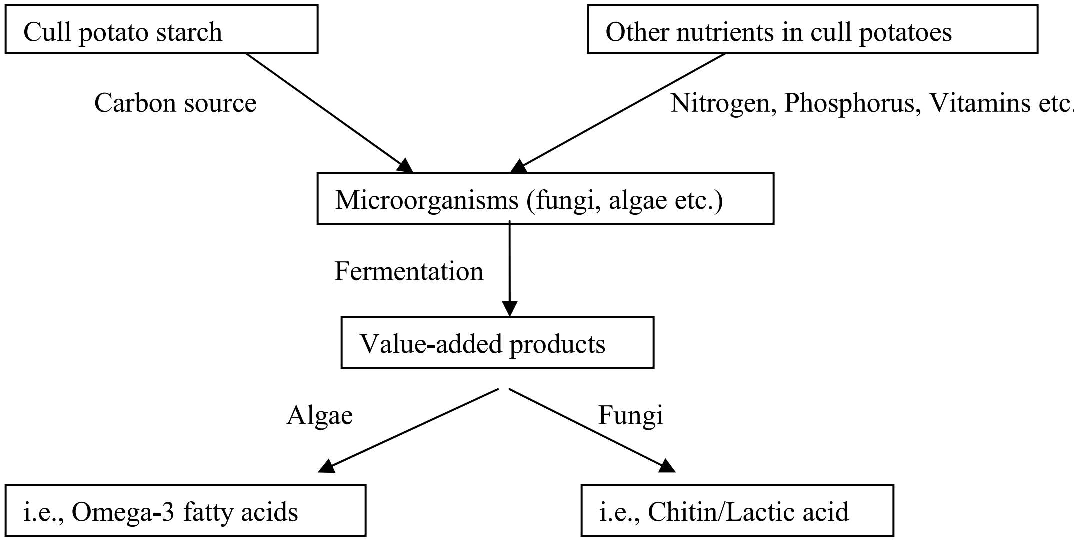
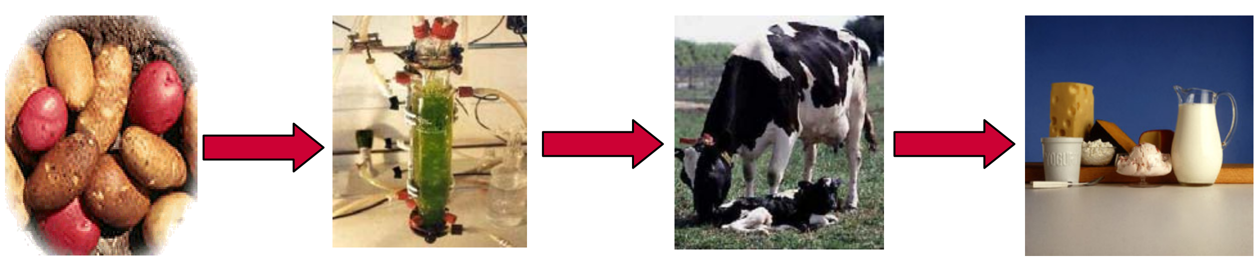


Figure 1. Converting cull potatoes into value-added products by fermentation processes.

Case I. Producing omega-3 polyunsaturated fatty acids from cull potatoes

Omega-3 polyunsaturated fatty acids, DHA (docosahexaenoic acid) and EPA (eicosapentaenoic acid), play important roles in regulating various human physiological functions and treating diseases. The recent clinical studies show that DHA and EPA are beneficial for treating Alzheimers disease and heart diseases. Also, DHA is the component of the photoreceptor cells of infant retina tissue. The inclusion of supplementary DHA in infant formulas is strongly recommended by the World Health Organization. Both of these two fatty acids unfortunately cannot be synthesized by the human body. Fish oil is the conventional source of DHA/EPA. However, there are some limitations of fish oil such as peculiar taste, odor, stability problems, and the difficult and expensive purification of these acids from low-grade fish oil. Also, the fish stocks are subject to seasonal and climatic variations. Fish, like humans, are not capable of synthesizing omega-3 PUFAs *de novo*; they obtain those fatty acids by eating microalgae, which is the primary producer of omega-3 PUFAs.

Based on above fact, the research group at the Biomass Processing and Bioproduct Laboratory of WSU proposed a process to grow algae to produce omega-3 fatty acids. As shown in Figure 2, cull potatoes will be used as substrate for algal growth, the obtained algal biomass serve as feed-additive for cows, which will produce omega-3 enriched milk.



(A) **(B)** **(C)** **(D)**

Figure 2. Converting cull potatoes (A) into omega-3 fatty acids containing algae (B) and feed the algal biomass to cows (3) to convert the omega-3 fatty acids into milk (D)

DHA production from different carbon sources by the alga *Thraustochytrium aureum* (ATCC 30343) are shown in Table 1. It was found that the alga produced the highest DHA yield on glucose and starch.

Table. 1 DHA production by the alga *Thraustochytrium aureum* on different carbon sources

			DHA		
Carbon source	Biomass (g/L)	Lipid in biomass (%, w/w)	In biomass (mg/g)	In lipid (% w/w)	Yield (mg/L)
Fructose	1.2	0.9	6.1	64.5	7.2
Sucrose	1.1	1.7	12.3	74.5	13.5
Glucose	3.8	16.5	70.4	42.8	269.6
Starch	4.9	14.7	66.7	45.3	325.4
Lactose	1.1	1.7	11.3	65.2	11.9
Maltose	4.6	17.9	73.2	41.0	334.4
Linseed oil	5.5	25.2	12.1	4.8	67.0

Preliminary study of feeding omega-3 algae to cows has also bee reported by a research group at South Dakota State University (Franklin et al., 1999. Dietary marine algae increased concentrations of conjugated linoleic docosahexaenoic and transvaccenic acids in milk of dairy cows. *Journal of Nutrition*. 129: 2048-2052). It was reported that when feeding 4% of algal biomass into the cow diet, the produced milk contained 0.46-0.76 g DHA per 100 g of milk fat, while in the control (without algae fed), the produce milk contained no DHA.

Case 2. Producing chitin/lactic acid from cull potatoes

Chitin and lactic acids are another two value-added products which can be produced from cull potatoes by fungal fermentation. Chitin is the second most abundant polysaccharide in the world. It is widely used in water treatment, agriculture, and cosmetic and biomedical industry. Lactic acid is an important organic acid which is widely used as a food additive. It is also the precursor for poly-lactic acid, which is a biodegradable plastic. Fungal chitin and lactic acid production from cull potatoes has been developed by the research group at the Biomass Processing and Bioproduct Laboratory of WSU (Figure 3). The fungal strain, R*hizopus oryzae* NRRL 395, was chosen as the producer by directly growing on potato starch.

The yield, however, was still very low (around 33%) even under optimal conditions. One reason was that this fungal strain forms cotton-like mycelia, which decreased the mass transfer in terms of oxygen and nutrients -- this eventually decreased the lactic acid production yield and productivity.

To address above limitation, the researchers at WSU developed a new technique to form small fungal pellets. This technique involved addition of supporting medium to the fermentation system, and adjusting the appropriate fermentation conditions. This strategy significantly increased the lactic acid yield by generating favorable pellet morphology (data not shown). An invention disclosure has been filed recently with the university's research foundation on the technology.

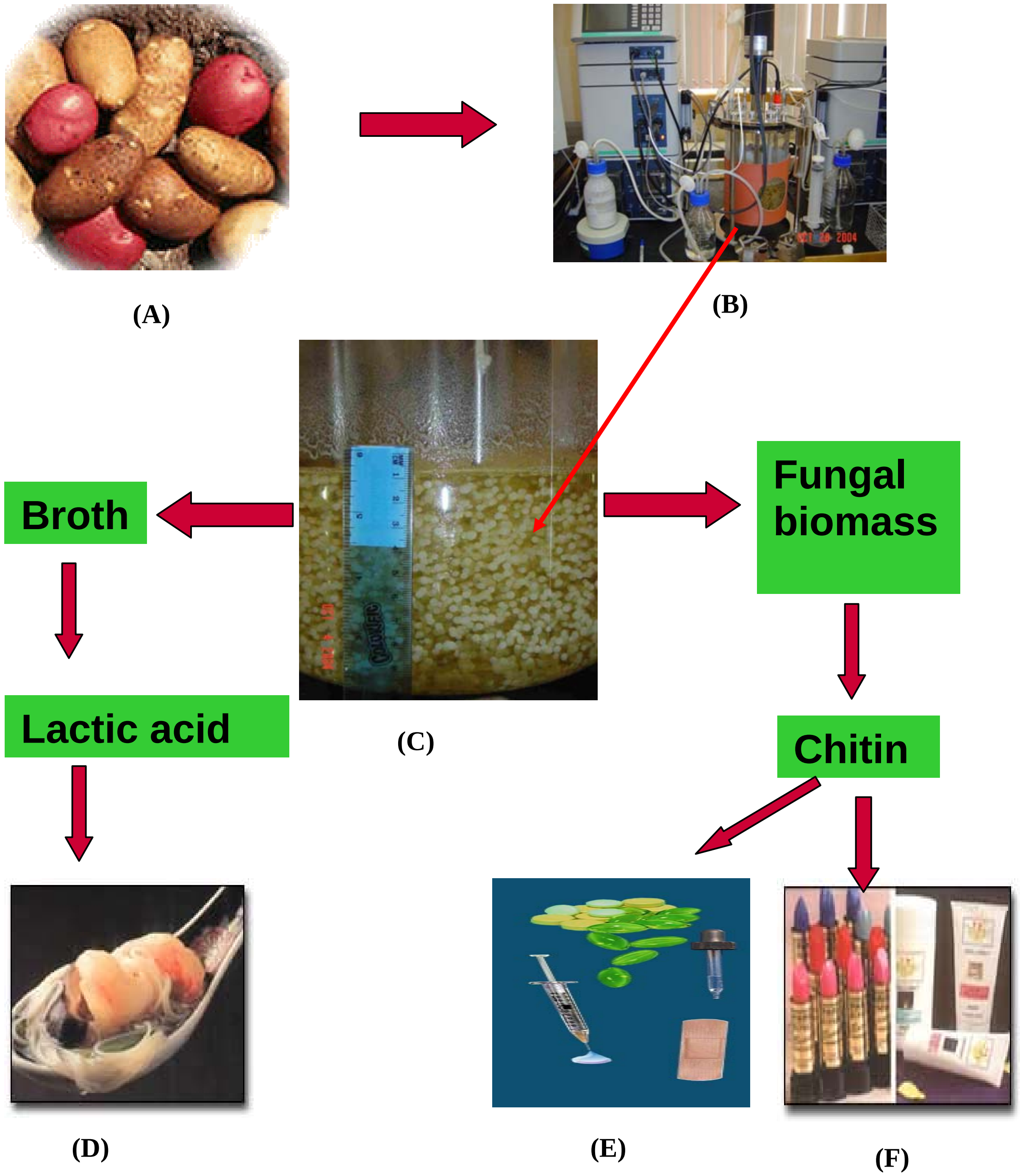


Figure 3. Converting cull potatoes (A) into chitin and lactic acid through a fermentation system (B). The fermenter is shown in (C). Lactic acid is used as food additive (D), while chitin is used for biomedical purpose (E) and cosmetics (F).

MARKET ANALYSIS AND ECONOMICAL ESTIMATION:

It is estimated that the annual worldwide demand of EPA is about 300 tons (pure EPA equivalent). Although the annual demand of DHA is not available, we believe that the number should be no less than EPA because the two fatty acids have similar functions. DHA demand is even higher than EPA since the infant formula requires DHA addition only. Currently, the production cost of algal biomass is about \$5/kg algal biomass produced. To be competitive with fish oil products, however, the algal production cost should be no more than \$4/kg algal biomass, as a result, the current technology to produce omega-3 fatty acids from algal cultivation is still not economically viable. To make the process economical, two tasks should be performed. One is to reduce the purification cost. Indeed, it has been reported that purifying 1 g of EPA/DHA from fish oil/algal biomass costs about \$150. In our proposed process, we address this issue by feeding the algal biomass to cows, so that the purification cost can be totally eliminated. The other task is to reduce the high feedstock/substrate cost. When pure glucose is used as substrate, it costs \$1.60 to produce each kg of algal biomass. If cull potatoes are used as feedstock, the feedstock/substrate cost in the omega-3 fatty acids production process could be significantly reduced. The future market for chitin is also very promising. The world wide market value for chitin is estimated at \$1.6 billion. Current chitin production is mainly from the shells of crab and shrimp. Converting cull potatoes into chitin by fungal fermentation provides an alternative source of chitin. The profitability of converting cull potatoes into chitin depends on the recovery/purification cost. Development of an environment-friendly recovery process is crucial for this potato-to-chitin process since strong alkaline is still the major reagent used for current chitin extraction process. The current U.S. market for lactic acid is around 40,000 ton/year. It is anticipated that there will be 5% to 8% annual increases in the next ten years. As half of lactic acid is produced from petroleum industry, using cull potatoes to produce lactic acid has a huge potential market as long as the production cost is competitive to petroleum industry.

In summary, our preliminary research results have shown that cull potatoes are a good substrate for algae to produce omega-3 polyunsaturated fatty acids and for fungi to co-produce chitin and lactic acid. This provides an alternative to efficiently utilize cull potatoes. In the future, our research effort will focus on enhancement of fermentation efficiency by using cheap substrate and development of a “robust” fermentation process. Also, the downstream process, i.e., recovery and purification of the value-added products from crude algal/fungal biomass or fermentation medium should be investigated to enhance the process efficiency.