Waste-Free Processing of Pea Grain to Optimize the Use of Starch Byproducts

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Abstract. Grain processing is a source considerable environmental pollution. 60% to 90% of the raw materials used in this industry are recyclable. This paper proposes a deep grain processing technology that can produce a variety of products with high added value. The authors hereof have developed and substantiated a waste-free pea grain processing technology that uses pea varieties selected by Federal Legume and Cereal Research Center, Oryol, Russia. This technology can produce high quality starch and its byproducts while also extracting the recyclables contained in pea grains: the germ and the seed husks, both of which have high added value.

1. Introduction
Grain processing is a source considerable environmental pollution. 60% to 90% of the raw materials used in this industry are recyclable [1].

Unless an innovative technology is in place, the industry will generate 126 million tons of waste in 2020 [2, 3]. However, plant-derived waste is rich in proteins, lipids, sugars, dietary fiber, etc. [4]. Value can be gained by extracting these compounds from food wastes to use natural resources more efficiently, lower the anthropogenic burden on the environment, improve the sustainability and economic competitiveness of agriculture and food industry [5, 6].

2. Relevance
One way to handle waste recycling in food processing is to develop and implement cutting-edge eco-friendly technologies for processing, including integrated grain processing [7].

Deep grain processing is currently deemed an advanced sector of economy [1] capable of laying foundations for industrial biotechnology to improve exports by producing a variety of processed products (Figure 1) with high added value [8].

Advancements in this area will help create Russian technology for waste-free grain / grain product processing, storage, and packaging to produce more grain, substitute imported products, reduce environmental burden, etc. [10, 11].

Russian deep processing market can utilize up to 15 to 20 million tons of grain per annum, and that does not include bioethanol for fuel, a product making which might consume an additional 50 to 80 million tons of grain per annum. Construction of deep grain processing facilities is estimated to pay off within five years [12]. This means such projects may utilize up to 7 million tons of grain as early as in 2020 [13].
The Russian Federation has approved public and sectoral programs that prioritize optimal use of recyclables and production wastes [1, 14]. A number of technologies have been developed under such programs, including deep processing of grain for fodder sugars; this technology consists of such steps as preparing raw materials and water, making grain suspension, liquefying such suspension by fermentation, and fermentative sugaring of starch [15, 16]. A project has been proposed to found a high-tech waste-free integrated grain processing facility to further replicate its experience across Russia’s grain processing industry [17]. One of the developed technologies can process wheat to make ethanol and protein products [18].

Pea grain is a promising raw material for waste-free production, as it can be used to make fatless flour (56...59% protein), concentrate (65...72% protein), isolate (at least 90% protein), flakes, starch, and dietary fiber (fiber and pectin) [19].

Researchers have proposed a technology for integrated pea grain processing to produce concentrate, extract, and pelletized oil cake; the technology has nearly 100% utilization rate and helps save plant resources by switching to waste-free production [8]. Another technology helps process peas to make concentrated (55%) protein products and pea starch by dry separation; a single production line can produce 5 to 10 thousand tons per annum [20]. A closed-loop waste-free zero-effluent eco-friendly technology uses baromembrane separation and lays foundation for processing peas into high-value, high-demand food supplements [19].

### 3. Formulation of the problem

Deep processing involves separating grains into high-value components, each of which has its use in the industry.

The objective hereof is to substantiate and develop a waste-free pea grain processing technology to extract native byproducts of starch production, namely husks and germs.

### 4. Theory

The raw materials used in development were pea varieties Temp and Spartak (round seeds), and Amior (wrinkled seeds) selected by the Federal Legume and Cereal Research Center, Oryol, Russia; the varieties different in starch and starch amylose content.

Extraction of starch as a process was affected by grain anatomy and chemistry. A thick seed husk consists mainly of fiber and hemicellulose; it accounts for up to 14.0% of the total weight of a seed and hinders starch extraction. Pea grains have large germs rich in lipids; these are easily oxidized and hydrolyzed, which deteriorates the quality of starch products. This is why husks and germs have to be
separated to the greatest extent possible to improve the quality of starch.

Biochemically, modern pea varieties feature high protein content (up to 30.0%) while being relatively poor in starch (up to 56.0%).

When assessing starch-containing raw materials for further processing, it is important to analyze proteins and their interaction with starch grains in solutions, as well as their ability to form carbohydrate-protein complex in combination with non-starch polysaccharides. This is why the protein complex of pea grains and its structure are not to be ignored when composing the reagents for starch extraction.

Modern pea varieties mainly contain the following proteins: water-soluble albumins; water-insoluble, neutral salt solution-soluble globulins; water- and alcohol-insoluble glutenins soluble in low-concentration alkaline solutions [22]. Pea grain seeds contain low amounts of lipids, fiber, and ash [23], all of which affect the starch extraction rate.

5. Results of experimental studies

When developing the herein presented technology for waste-free pea grain processing, the research team analyzed the grain structure and focused on maximizing the extraction of valuable components.

Organic, mineral, and metal impurities were removed from grains before processing. Then grains were peeled by a laboratory husk remover.

To destruct the raw material and weaken the bonds between starch grains and other components, peeled grain was soaked in water at 2...4ºC over 24 hours; the soaking reagent to grain weight ratio was 1:1. Then the extract was separated from soaked grains, concentrated, and dried.

The next step was to remove germs and dry them at 18...20ºC at a relative humidity of 11.0% at max.

The remaining grains were soaked in water (1:1), crushed to make slurry, then poured unto a 100-µm silken mesh; pulp was separated from starch with water at 2...4ºC until the rinsing waters ran clean. After each sieving, pulp was mixed with another portion of water in a tank; the mixture was sieved again. Washed pulp was dehydrated and dried at about 50ºC.

The resulting starch-protein suspension was separated into gluten suspension and starch milk. Gluten suspension was dehydrated, dried at about 50ºC, then sieved to make dry gluten. Starch milk was washed with 0.1M NaCl solution at 2...4ºC over 30 minutes. Some of the liquid was then poured, and the settled starch was washed in water at 2...4ºC over 30 minutes.

Then this starch was placed on a filter and once again washed with water at 2...4ºC until water ran clean. After that, we dehydrated starch with a small amount of 96.0% vol. ethyl alcohol, dried at 18...20ºC to about 13.0–14.0%, and sieved through a 100-µm silken mesh. The resulting fine-powdered starch was packaged in paper bags and stored at 25ºC or below, 75% relative humidity or below, for a maximum of 24 months.

This technology effectively produces high-quality starch and its byproducts: extract, pulp, gluten, and process water, see Figure 2.

![Figure 2. Pea grain processing products.](image)

Any further processing of byproducts increases the production costs. However, this increased is offset by the greater consumer value of final products. Gluten concentration produces high-protein products: pea protein concentrate and isolate. Pulp can be partially dehydrated or dried for use as fodder in...
animal farming. Concentrating the water produced by grain processing makes nutrient media for enzyme industry.

Besides, this technology extracts secondary grain components, namely germs and husks. Pea husks contain fiber and pectins, which are used in food supplements. The germ is a abundant in bioagents and can thus be used for food or as a process medium.

The yield of starch, husks, and germs is shown in Table 1.

Round-seeded varieties (Temp, Spartak) had the lowest starch loss. The loss of husks and germs were insignificant, with a yield of 94.3 to 98.8% and 93.3 to 94.2% of the maximum projected output.

| Table 1. Starch, husk, and germ yield of pea grain processing. |
|---------------------------------------------------------------|
| Indicator | Temp | Spartak | Amior |
|-----------|------|---------|-------|
| Concentration (% of grain weight) | 48.28 ± 0.12 | 48.52 ± 0.00 | 25.94 ± 0.08 |
| starch | 7.57 ± 0.07 | 7.86 ± 0.06 | 10.86 ± 0.05 |
| husks | 1.39 ± 0.01 | 1.28 ± 0.00 | 1.20 ± 0.01 |
| germ | 33.2 ± 0.14 | 30.0 ± 0.16 | 14.3 ± 0.16 |
| Yield (% of total grain weight) | 7.48 ± 0.02 | 7.75 ± 0.04 | 10.22 ± 0.02 |
| starch | 1.31 ± 0.02 | 1.20 ± 0.01 | 1.12 ± 0.01 |
| husks | 68.8 | 61.8 | 55.1 |
| germ | 98.8 | 98.6 | 94.3 |
| Yield (% of maximum possible yield) | 94.2 | 93.8 | 93.3 |

6. Conclusion
The developed waste-free pea grain processing technology produces native starch and its byproducts (boiled extract, pulp, and gluten) plus high-value added germs and husks.

The starch, husk, and germ yield is 55.1 to 68.8%, 94.3 to 98.8%, and 93.3 to 94.2% of the maximum possible yield, respectively.

Implementing this technology will help optimize the use of starch production byproducts and reduce the environmental burden.

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