Development of a multi-tier malt-growing apparatus for the needs of a craft brewery

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Abstract. The article presents a multi-tier conveyor malt-growing apparatus, which is designed for growing malt in small enterprises, makes the process continuous and efficient by moving the germinating layer of grain without damaging the sprouts. It allows the automatic adjustment of technological modes depending on the type and quality of grain by controlling the supply of condensed air in specified temperature ranges, ensures environmental friendliness of production due to water recycling, energy saving due to the sloping arrangement of tiers and reducing energy consumption for grain agitation. It allows the producing of special malt varieties from various agricultural plants. A comparative analysis of conveyor systems has been carried out and their significant disadvantages have been identified that do not allow the systems to be used for malt production. Significant advantages of using the developed multi-tier malt plant are shown. Exposure to an electromagnetic field at the soaking stage contributed to an increase in the germination of barley. It was found that short-term UV irradiation of barley in the first hours of swelling led to an increase in seed germination. The expediency of using the new conveyor malt-growing apparatus to produce special malts for craft brewing is shown.

1. Introduction

To date, the brewing industry in Russia has reached a high level of development. Beer produced in Russia is exported to different countries. A large share of the beer market in Russia (72.5%) is occupied by large brewing companies that stand out in technological stability and a classic range of beer drinks [1, 2]. The remaining share is held by regional beer producers, medium and small breweries. Craft brewing is becoming more and more promising and occupies more than 40% among medium and small breweries. This is due to the growing need for new flavours and the popularity of exclusive and original beers among connoisseurs of foamy beverages [3, 4].

Due to the active development of craft brewing, the demand for raw materials is also increasing. To expand the range of drinks and release new kinds of beer, one must use an innovative malt. The main and most common source for beer production is barley malt. Today, there are more and more types of beer that use malt from various cereals in their composition. In addition to barley, wheat, rye, oats, corn, rice, buckwheat and other grains are used [5, 6]. The combination of different types of malt allows craft breweries to create unique recipes for beer drinks [7, 8].
Medium and small breweries buy malt mainly abroad. But many craft breweries are turning to domestic malt, as it is more cost-effective. This malt is half the price of the imported one. The total volume of malt sales from large plants to small breweries is growing every year. However, the development of the local raw material base would make possible a push in the development of small and medium-sized brewing. The more developed the local manufacture of malt, the better craft breweries are developed. Unfortunately, brewing malt is produced only at large enterprises, and to create unique beers, unique malt varieties are needed.

Malt is an extremely important raw material for brewing. Malt is a partially germinated and dried grain of cereals. During germination, enzymes accumulate in the grain. They are necessary for further conversion of starch into low-molecular sugars, required for further nutrition of yeast during fermentation [9, 10].

Modern malting plants with a capacity of 100-250 thousand tons per year are equipped with complex automated continuous lines and maintain stable quality for certain malt varieties. This is mainly the production of light caramel and dark malt. To date, malting apparatuses on the following principles have been developed: based on flow motion, box-, drum-, shaft-, tower-geometry, an apparatus with a mobile bed, and there are round-section apparatuses. They all are introduced into production. Such machines occupy a large area and do not have a fully improved design. Grain agitators on them have a high metal content, high-energy consumption, and they damage the grain sprouts when mixing it.

To date, there are known conveyor-type plants designed for germinating grain for using it as vitamin feed for animals and birds [11, 12]. These machines are equipped with conveyors positioned one above the other and with irradiation lamps. However, these plants cannot be used for the production of brewage malt, since they do not regulate the temperature regime of germination and do not maintain humidity in the grain layer; the irradiation lamps installed between the tiers contribute to the process of photosynthesis and accelerated formation of a green sprout with the gordein alkaloid (Hordenine). This gives drinks an unpleasant taste, while there is a loss of mass of dry substances of the grain to form a seedling, which is extremely undesirable in the production of malt. The apparatuses do not provide ways to reuse water, which is unecological: it increases the discharge of untreated wastewater [13]. The number of conveyor tiers is not enough for the production of malt from long-sprouting grain. The "Conveyor plant for grain germination" [14] uses a source of microwave electromagnetic radiation with a magnetron of continuous wave-generation with a frequency of 915 MHz to stimulate the growth processes of grain. This heats the grain mass. The microwave effect has a strong bactericidal effect, but reduces the activity of the most important amylolytic and proteolytic enzymes that are necessary for obtaining high-quality malt [15].

In general, the production of beer in small breweries is organized in limited spaces. A small brewery needs about 80 tons of malt per year to complete the full production cycle. With a malt-growing apparatus at one’s disposal, one can reduce the cost of the product and can have an uninterrupted supply of raw materials [16, 17].

2. The purpose of the study
For small and medium-sized breweries, it is possible to optimize the cost of producing their own unique malt and original beers. This will reduce the cost of the raw material and lead to a reduction in the cost of the final product. But the organization of one’s own production is difficult due to the lack of special malt-making equipment. Therefore, the aim of the research was to develop malt-making equipment adapted to the needs of craft brewing.

3. The object of the study
The object of the study was experimental conveying malt-growing machine and the following malting barley (Hordeum vulgare L.) varieties: Siberian sort of “Acha” grown in Tulun district of the Irkutsk
region, sort of “Cedar” grown in the Krasnoyarsk region, and the cultivar “Scarlett” from the Kursk region.

4. Materials and methods

4.1 Method for producing malt in a conveyor malt-growing apparatus

The aforementioned barley varieties were germinated in the developed conveyor malti-growing apparatus presented in Figure 1.

![Figure 1. Scheme of the device of the conveyor malt house: 1 – loading funnel; 2 – nozzle; 3 – magnetic nozzle; 4 – UV-germicidal lamp; 5 – supporting rollers; 6 – layer formers; 7 – electric motor; 8 – gear motor; 9 – guides; 10 – chain transmission; 11 – stretching rollers; 12, 13, 14, 15, 17, 18, 19, 20, 21, 23 – conveyor tiers; 16 – evaporative cooler; 22 – discharge hatch; 24 – lower compartment of the casing; 25 – water collector; 26 – submersible pump; 27 – pressure line.](image-url)

Loading of barley into the malt house was carried out after removal of weed impurities and sorting of grain. The sifted and sorted grain with a moisture content of 13.5% was fed to the loading funnel 1, to the upper belt conveyor 12, which is supported by rollers 5. Side guides 9, do not allow the grain to fall out of the belt conveyor, and the layer shapers 6 align the grain layers. Tiers 12, 13, 14, 15 installed with a slope reduce the load on the engine, ensure that the water flows to the lower levels and make the process of moving and humidifying the grain more efficient. When the grain is fed to the funnel 1, the belt conveyors are rotated using a gear motor 8 and an electric motor 7.

The apparatus is constructed to have a continuous grain loading. The continuity is ensured by moving the conveyor belt. When the surface of a mobile tier is fully covered, the grain is gradually poured to the lower level, while the belt conveyors move along the guides 9. Supporting rollers 5
installed along the length of the belt conveyors prevent the belt from sagging. The stretching rollers 11 prevent the chain transmission 10 from slipping when the belt conveyors are fully loaded.

A UV-germicidal lamp 4 is installed above the upper tier under the lid of the malt chamber. Treatment with ultraviolet radiation of 250-300 Nm neutralizes bacteria, viruses and other primitive organisms and prevents their reproduction.

The conveyor malt-growing apparatus is designed to provide conditions for germinating grain in the phases of its development. The top 4 tiers 12, 13, 14, 15 are made of food-grade corrugated textile-rubber belt; they retain and transfer moisture to the grain layer, thereby creating conditions for wetting the seeds to a humidity of 43-47%, necessary for the seeds’ swelling and germination. The remaining 6 tiers 17, 18, 19, 20, 21, 23 are made from a conveyor belt, which provides a good aeration of the grain layer and prevents its waterlogging and loss of dry substances. This eliminates the risks of anaerobic respiration of the grain and the formation of undesirable metabolic products. From the lower tier 23, the germinated grain is withdrawn through the unloading hatch 22. Then the resulting malt is sent to dry.

The conveyor malt-growing apparatus has a magnetic nozzle 3, which acts on the water with a frequency of magnetic oscillations in the range from 0.1 to 100 Hz. Many scientific papers have been devoted to structuring water with a magnetic field. Structured water increases the permeability of biological membranes, helps to better absorb nutrients and accelerate seed germination [18, 19, 20]. Water under pressure created by the pump 26 passes into the pressure line 27, then through the magnetic nozzle 3 is fed to the nozzle 2 for feeding to the grain layer. The remaining water flows down the tiers, is collected in the lower part of the plant 24 in the collector 25 and is pumped through the submersible pump 26 to the upper part of the apparatus, then reused to moisten the grain layers.

Malting is carried out at a temperature of 12 to 14°C to maintain the development of the embryo and inhibit the development of microorganisms. Control and regulation of the temperature in the malt-growing apparatus is carried out using a thermometer mounted on the inner wall of the malt chamber and connected to the fan drive of the evaporative cooler 16 via a starting relay that automatically turns the fan on and off.

4.2 Determination of barley and malt quality indicators

Studies of the qualitative characteristics of barley (table 1) were performed using standard methods [21, 22].

The activity of amylolytic enzymes was determined by the Windisch-Kolbach method, which consists in the fact that a 2% starch solution is saccharified with a malt extract of the analyzed malt at a pH of 4.3 and the resulting maltose is determined iodometrically [21].

5. Discussion of the results

The qualitative characteristics of the studied barley met the requirements of class 1 according to GOST 5060-86 and are shown in table 1.

| Table 1. Characteristics of malting barley varieties |
|-----------------------------------------------|
| Technological quality indicator | GOST requirements | “Acha” | “Cedar” | “Scarlett” |
|----------------------------------|--------------------|--------|--------|-----------|
| Humidity, class I, %            | No more than 15    | 12.0   | 11.8   | 12.0      |
| Protein, %                      | No more than 12    | 10.4   | 9.6    | 11.7      |
| Size, class II, %               | At least 60        | 77     | 94.1   | 78.7      |
| Fine grain, class I, %          | No more than 5     | 4.3    | 1.2    | 2.7       |
| Viability, %                    | At least 95        | 98     | 74     | 73.4      |

As a result of growing barley on a conveyor malting plant, malt with high amylolytic activity was obtained on the 4th day of germination, table 2.
Table 2. The progress of amylase activity in malting barley of Acha variety

| Days of germination | 1    | 2    | 3    | 4    | 5    |
|--------------------|------|------|------|------|------|
| Amylolytic activity, units / g | 134.8 | 190.5 | 218.1 | 235.2 | 196.8 |

The water pumped in the magnetic nozzle 3 is structured with magnetic fields. From the results obtained in the experiment (table 3), it can be seen that the amylolytic activity in the studied malt samples is higher than in the control samples. Figure 2 shows that the germination rate of seeds soaked in structured water is higher than in control samples. Thus, the influence of an electromagnetic field at the stage of soaking contributes to an increase in the rate of barley germination and an increase in the amylolytic activity of malt.

Table 3. Amylase activity of malt obtained using magnetic structured water

| Conditions       | "Acha" | "Cedar" | "Scarlett" |
|------------------|--------|---------|------------|
| Control          | 182    | 220     | 194.09     |
| Structured water | 235    | 273     | 257        |

Figure 2. Change in the germination of barley when the grain is soaked in water structured by a magnetic field

The use of ultraviolet irradiation with a bactericidal purpose in a conveyor malt-growing apparatus also affects the germination of seeds. Figure 3 shows that short-term irradiation of barley in the first hours of swelling leads to an increase in seed germination. UV irradiation after 12 hours of seed swelling does not contribute to a significant increase in germination.

Figure 3. Influence of UV irradiation intensity in different periods of grain soaking on the germination of seeds of barley Acha
6. Conclusion

The developed conveyor malt-growing apparatus implements such technological methods that are aimed at solving the tasks: small size of the equipment, the ability to regulate technological modes, the ability to produce malt from various agricultural crops – wheat, oats, millet, etc. The economy of production space is achieved by simultaneously germinating grain on several planes, arranged in tiers one above the other. This method allows one to get more germinated malt per unit of production area. The results of the experiment showed that the methods of physical influence on germinating seeds provided in the conveyor malt-growing apparatus have a positive effect on germination and increase amylolytic activity – the most important technological indicator of malt.

![Image](https://example.com/image.png)

**Figure 4.** The laboratory instalment assembled according to the developed model of the conveyor malt-growing apparatus; located at the Department of Chemistry and food technology named after Professor Tuturina V. V. in the Institute of High Technologies at the Irkutsk National Research Technical University (INRTU)

The method of water recycling provided in the malt-growing apparatus makes malt production more environmentally friendly and waste-free, while creating conditions for using methods of enriching malt with solutions of nutrient salts and for using, if necessary, growth stimulants. In research aimed at studying the methods of intensification of malting and finding a way to enrich malt with selenium, the effectiveness of this instalment was shown [23]. The conveyor malt-growing apparatus developed by the INRTU is patent-pending as a useful model; the confirmation id is I-92/20 of 17.01.2020.

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