ства с холодильником и предубойным содержанием, санитарно- бытовыми помещениями и др. вспомогательными службами; -обеспечение противопожарных требований, норм санитарии, экологичности производства и безопасности труда.

Технолог-проектировщик является ведущим звеном в структуре проектирования. На него возлагается обязанность принять такие технологические решения по основному производству и вспомогательным процессам, которые позволят вырабатывать продукцию по установленной программе, обеспечивающей соблюдение действующих нормативных санитарных, ветеринарных и технических требований на вырабатываемую продукцию и условия ее производства.

Вот здесь следует отметить, что действующие отраслевые нормативы ВНТП 540/697-92 и ВСТП-6.04.92 и др. уже устарели и по многим позициям не соответствуют международным требованиям, в том числе по международным санитарным, пожарным, экологическим требованиям, требованиям охраны труда.

В связи с ожидаемым вступлением России во всемирную торговую организацию, многие предприятия ориентируются на экспорт своей продукции, что потребует обязательное учитывание международных требований, стандартов, действующих в странах ЕС.

Хорошим примером могло бы послужить в области нормотворчества сотрудничество института «Гипрорыбфлот» (Санкт- Петербург) с Инспекционной службой России- «Нацрыбкачеств», присваивающей производственному предприятию номер объекта на право экспорта продукции уже на стадии проектирования.

В связи с вышеизложенным это можно привести в соответствие Минсельхозом РФ путем размещения заказа на корректировку ВНТП, ВСТП и др. нормативных документов в ведущих отраслевых проектных организациях.

Анализ современных производственных предприятий отрасли показал, что ассортимент выпускаемой продукции довольно широкий. Возможность использовать сырье на проектируемом предприятии не только выращиваемое в данном регионе, позволяет вырабатывать из него продукцию в ассортименте, удовлетворяющем потребности рынка. Все более возрастающие требования к охране окружающей среды и экологичности производства обязывают проектные организации уделять особое внимание выбору местоположения создаваемого производства - наличию санитарно- защитной зоны проектируемого объекта (стройки) до селитетной территории и отсутствия влияния расположенных вблизи производств.

Жизнедеятельность проектируемого предприятия зависит от наличия на площадке инженерных сетей и сооружений и возможности подключения к ним. При работе над проектом необходимо уделить должное внимание расположению зданий основного, вспомогательного производства, инженерного и складского назначений, определению взаимоувязки высот производственных помещений, определению нагрузок на полы и перекрытия, агрессивности воздушной среды и сточной жидкости (водосливам). Немаловажное значение имеет внутренняя отделка стен, перегородок, материалу покрытия полов.

Принимая конструктивную схему здания основного производства следует обратить внимание на использование несущих конструкций (в железобетонном варианте) без образования выступов (полок) – «пылесборников».

Необходимо помнить, что все материалы, используемые при строительстве предприятий мясной промышленности должно соответствовать перечню материалов разрешенных к применению Госсанэпиднадзором.

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TANEVA D.S., assistant, RASHEVA V.D., doctor, associate professor, VALCHEV G.I., doctor, professor, PROKOPOV Ts.V., doctor, associate professor
University of Food Technologies, Plovdiv

INVESTIGATION OF SPRAY DRYING PROCESS OF BIRCH EXTRACT

Abstract. The spray drying process of water-alcohol birch extract was investigated. A Büchi model 190 laboratory-scale mini spray dryer was used. The effects of various experimental parameters such as inlet air temperature, extract feed flow rate and drying air flow rate on the outlet air temperature, residual moisture content and dried product yield were evaluated by means of experimental full factorial design. The inlet air temperature had the greatest effect on the outlet air temperature and powder moisture content. Regression equations are presented for the inlet-outlet dependences. A second-order polynomial model was established for the influence of inlet variables on the dried product yield.

Key words: spray-drying, birch, modeling, yield, temperature, moisture, air, cleaning.

Introduction. The essential oil plants and herbs are of great interest for use in the food, cosmetics, sugar and pharmaceutical industries. These plants contain very useful biologically active substances such as essential oils, alkaloids, flavonoids, etc. Dried extracts of such plants can be stored easily and for a long time, and their components easily used. Liquid plant extracts are obtained by extraction with various solvents such as water, ethanol, methanol, glycol, and etc., or solvents mixtures. Therefore the extracts are concentrated for solvent recovery by vacuum apparatuses. Dried extracts are obtained from the concentrates by drying. The final product is a powder with certain moisture content. It is established that spray drying is the most useful process for the manufacture of such products [1].

A growing number of different studies are carried out on the spray drying of various raw materials such as model sugar-rich foods [8], fruit and vegetables juices [4, 7], pharmaceuticals [6], etc. In all studies the influence of process variables such as inlet air temperature, feed flow rate, atomizing air flow rate and drying air flow rate on the outlet air temperature, residual moisture content, powder product yield, particle size and distribution in the dried product, morphology and other quality parameters of the obtained dried powder product were investigated.

Different mathematical models and optimizations of spray drying process have been reported in literature. Non-linear models concerning the yield of spray dried

Table1

Characteristics of the birch extract

Parameter	Value	Analysis method
Dry matter	10.0 %	Weighting
pH	4.6	pH-meter
Total sugars	3.51 %	Dubois
Viscosity	18.4±5 mPa.s	RV-viscosimeter
Methanol	0.236 g/dm^3	Gas chromatography

products have been described [7, 8].

A lot of problems are established during the spray drying of amorphous, sugar-rich and volatile component containing products. One of these well known problems is the low dried product yield because of stickiness in the spray drying of such products causing material adhesion on the dryer surfaces. Many of the smallest particles cannot be recovered in the lab-scale apparatuses because they do not efficiently deposit in the cyclone and because their low masses cause them to be drawn up into the outlet air which also lead to low powder yield [4,5,7].

Another important problem of spray drying is the passage of volatile components from the product into the drying air leading to quality losses and environmental pollution with volatile organic components and odors [5].

The aim of this study was to investigate the influence of spray drying parameters on outlet air temperature, residual moisture content and the dried product yield during laboratory-scale spray drying of water-alcohol birch extract with a possibility for outlet air cleaning by condensation of some pollutants.

Materials and methods. Industrial water-alcohol birch (Betula alba) extract was used in this study with defined characteristics (table 1).

The laboratory-scale installation used consisted of a Büchi laboratory mini spray dryer model 190, air compressor and cooling block. Description of the installation and methods of measurement of the process parameters have been described in our previous publication [2].

Full factorial experiment of the type 2^3 was carried out (table 3). For investigation of the influence of the process parameters on the dried product yield optimal composite experiment plan with star points was used. The star shoulder length was $\alpha = \pm 1$ (table 4).

The effects of three major process parameters, such as:

x_1 – extract feed flow rate, cm^3/h;

x_2 – air flow rate at the installation end, m^3/h;

x_3 – inlet air temperature at the drying chamber entrance, ^{0}C,

on the outlet air temperature at the end of the drying chamber, residual moisture content and the dried product yield were investigated.

Levels of the experimental factors and intervals of variation were selected by preliminary experiments and are presented in table 2.

All experiments were carried out under stable environmental conditions of mean relative air humidity and ambient air temperature 49.3±3.2% and 20.2±0.9^{0}C respectively. The atomization air flow rate was 700 Nl/h, and ambient temperature of the feed extract was used. Triplicate experiments were carried out.

Gohren's, Student's and Fisher's criteria were used for statistical data treatment [3].

The dry matter content of the extract and the dried product was measured by the weighting method. The total sugar content of the extract was measured by the Dubois method. The extract viscosity was measured using a Brookfield RV-viscosimeter RV – II + pro at 21.2^{0}C. The RV–02 spindle type was used with rotation rate of 100 min^{-1}, sample time of 1 min, and an RTD temperature sensor. The pH level of the extract was measured using a Milwaukee SM102 pH-meter at 20^{0}C.

The outlet drying air from the spray dryer was cooled in the cooling block and the obtained condensate was collected. The mean inlet air temperature was 42.2±0.8^{0}C and the mean outlet air temperature was 10±0.6^{0}C. The cooling agent inlet temperature at the cryostat used was -6.0^{0}C. The essential oil content in the obtained condensate was measured by extraction with diethyl ether. The methanol content of the extract and the obtained condensate was measured by gas chromatography. A Shimadzu GC 17A gas chromatograph was used consisting of a flame-ionization detector, 30 m x 0.32 mm x 0.25 μm TRB-WAX column on "Teknokroma" at the following temperature regime: 40^{0}C with 10^{o}C/min to 80^{0}C, 10 min constant temperature and 15^{0}C/min to 200^{0}C with 2 min constant temperature. The injector temperature was 229^{0}C and the detector temperature was 250^{0}C. The flowing gas was N_2 with split ration of 1:10 and flow rate of 1.00 cm^3/min. The injected sample quantity was 1 μl.

Table 2

Levels of the experimental factors and intervals of variation

Factor	Extract feed flow rate, cm^3/h	Air flow rate at the end of installation, m^3/h	Inlet air temperature, ^{0}C
code	$X_1 = \frac{x_1 - 231.5}{37.5}$	$X_2 = \frac{x_2 - 54.55}{2.15}$	$X_3 = \frac{x_3 - 175}{5}$
Interval of variation	37.5	2.15	5
Mean level	231.5	24.55	175
High level	269	26.7	180
Low level	194	22.4	170

Results and discussion.The results on the characteristics of the used birch extract are shown in table 1.

The levels of the experimental factors and intervals of variation are presented in table 2.

The results on the influence of the input variables on the outlet air temperature at the end of drying chamber (y_1) and on the residual moisture content of the dried product (y_2) are presented in table 3.

Table3

Experimental data on the spray drying process concerning outlet air temperature at the end of drying chamber (^{0}C) and residual moisture content of the dried product (%)

№	X$_1$	X$_2$	X$_3$	$y_{1\ measured}$, ^{0}C	$y_{2\ measured}$, %	$y_{1\ calculated}$, ^{0}C	$y_{2\ calculated}$, %
1	+1	+1	+1	94.0	4.1	93.9	3.9
2	+1	+1	–1	88.0	4.7	88.3	4.6
3	+1	–1	+1	88.7	4.6	89.0	4.5
4	+1	–1	–1	84.0	5.3	83.4	5.2
5	–1	+1	+1	96.3	3.7	96.0	3.9
6	–1	+1	–1	90.3	4.6	90.4	4.6
7	–1	–1	+1	91.0	4.4	91.1	4.5
8	–1	–1	–1	85.3	5.1	85.5	5.2

On the basis of the results from the full factorial experimental design (table 3), the following regression equations were established:

$$y_{1calulated} = 89.7 - 1.025\left(\frac{x_1 - 231.5}{37.5}\right) + 2.45\left(\frac{x_2 - 24.55}{2.15}\right) + 2.8\left(\frac{x_3 - 175}{5}\right), {}^0C$$

$$y_{2calculated} = 4.5625 - 0.2875\left(\frac{x_2 - 24.55}{2.15}\right) - 0.3625\left(\frac{x_3 - 175}{5}\right), \% \quad (1, 2)$$

The polynomial regression coefficients were calculated and statistical data treatment showed that the models obtained were adequate.

Table 4

Experimental data on the spray drying process concerning the dried product yield (%)

№	X_1	X_2	X_3	$y_{3\ measured}$, %	$y_{3\ calculated}$, %
1	+1	+1	+1	27.0	26.2
2	+1	+1	–1	23.7	22.9
3	+1	–1	+1	23.0	23.9
4	+1	–1	–1	20.9	20.6
5	–1	+1	+1	27.0	27.8
6	–1	+1	–1	24.0	24.5
7	–1	–1	+1	26.2	25.5
8	–1	–1	–1	21.7	22.2
9	+1	0	0	21.2	22.3
10	–1	0	0	25.0	23.9
11	0	+1	0	26.0	26.3
12	0	–1	0	24.3	24.0
13	0	0	+1	26.3	26.2
14	0	0	–1	22.7	22.8

The established outlet air temperature range was from 85.3 to 96.3^{0}C (table 3). The obtained linear regression model adequately presented the investigated object within the frame of the used intervals of variation of the experimental factors (fig. 1). This model can be used for process optimization. The increase in the extract feed flow resulted in a decrease in the outlet air temperature, but the increase in the air flow rate and inlet air temperature led to an increase in the outlet air temperature. Inlet air temperature had the greatest effect on the outlet air temperature whereas the extract feed rate affected it the least. Results showed that an increase in the extract feed flow rate by one point led to a decrease in the outlet air temperature by about 1.025%, and the increase in the air flow rate and inlet air temperature by one point resulted in an increase in the outlet air temperature by about 2.45% and about 2.8% respectively. The obtained data were in accordance with the results reported by other authors for the spray drying of different products [4,7].

The established range of the residual moisture content of dried product was from 3.7 to 5.3%. The obtained linear regression model adequately presented the investigated object within the frame of the used intervals of variation of the experimental factors (fig. 2). This model can also be used for process optimization. The increase in the air flow rate and inlet air temperature by one point led to a decrease in the residual moisture content by about 0.2875% and about 0.3625% respectively. The results showed that the inlet air temperature had the greatest effect on residual moisture content.

The results on the influence of the input variables on the dried product yield (y_3) are presented in table 4.

On the basis of the results from the optimal composite experimental design with star points (table 4) the following regression equation was established:

$$y_{3calculated} = 24.275 - 0.8\left(\frac{x_1 - 231.5}{37.5}\right) + 1.15\left(\frac{x_2 - 24.55}{2.15}\right) + 1{,}66\left(\frac{x_3 - 175}{5}\right) - 1.175\left(\frac{x_1 - 231.5}{37.5}\right)^2 + 0.875\left(\frac{x_2 - 24.55}{2.15}\right)^2 + 0.225\left(\frac{x_3 - 175}{5}\right)^2$$

The second-order polynomial regression coefficients were calculated and statistical data treatment showed that the model obtained was adequate.

The established range of the dried product yield in this study was from 20.9 to 27.0%. The obtained second-order regression model adequately presents the investigated object within the frame of the used intervals of variation of the experimental factors (fig. 3) and can be used for optimization.

The results confirmed material adhesion on the dryer surfaces leading to low product yield as established by other authors [4,7].

The increase in the extract feed flow rate resulted in a decrease in the product yield whereas the increase in the air flow rate and inlet air temperature led to an increase in the yield. The mean quantity of the cold outlet air condensate on the end of the cooling block was 112.3±14.6 cm^3. The results from the condensate analysis showed that the methanol content was 0.057 g/dm^3 and the essential oil mean content was 0.025±0.016 %. These results led to the conclusion that some air purification was performed.

Conclusion.

1. The influence of the extract feed flow rate, air flow rate and inlet air temperature on the outlet air temperature at the drying chamber end, the residual moisture content and dried product yield were established during spray drying of birch water-alcohol extract in a laboratory-scale installation.
2. Adequate mathematical models describing the input-output process parameter dependences were established. The presented models can be used for optimization.
3. The possibility of purifying the installation outlet air by condensation of some air pollutants was evaluated. It can be applied in the practice.
4. Future work is needed concerning the optimization of spray drying of birch extract and the degree of outlet air purification.

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