

Mathematical Representation of Determination of Equilibrium Concentrations of Light Volatile Components in Multicomponent Mixtures

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Abstract. The scientific research illustrates that the authors developed mathematical expressions for calculating the equilibrium concentrations of light volatile components in the process of driving multicomponent mixtures with hot water vapor. The process of deodorization of vegetable oil was considered as a mixture in the formulation of mathematical equations. The developed equations can also be used in the driving processes of various liquid multi-component mixtures.

Keywords: concentration, component, partial pressure, determinant, quasi-apparatus, deodorization.

Introduction. The final process in the technological system for the production of vegetable oils is deodorization of the oil, which is accompanied by mass transfer between phases. In deodorization of oil, the light volatile components that give it the smell and flavor are separated by driving with hot water vapor. Therefore, the process of oil deodorization is researched as driving multicomponent mixtures. In our research, we consider the elements and phases of the oil deodorization apparatus as a separate quasi-apparatus. Deodorization of oil in the bubble method is carried out by passing hot water vapor through a liquid layer. In this process, hot water vapor flows through the liquid layer forming bubbles, while absorbing and carrying away the light volatile components. Massification between phases takes place on the surface of the formed bubbles. In bubbling, the smaller the diameter of the bubbles, the greater their number and the larger their total surface, the more intense is the massing between phases. Chain nozzles are placed in the bubbling zone of the newly designed oil deodorizing apparatus that we offer. In order to formulate a mathematical representation of the elements of the deodorization process in the chain-tube quasi-apparatus, we adopt the constraints listed below:

- worker in the zone pressure immutable;
- since self-evaporation of oil during deodorization is very small, we accept its amount as constant;
- vegetable oil - the mixture obeys Raoult's law;
- in the working zone, the physic-chemical properties and thermomechanical parameters of the oil components are assumed to be constant, and the average value of the concentrations within their variable limits is obtained;
- an ideal mixing model is adopted for hydrodynamic structures of flow of liquid and gas phases;
- Diffusion resistance is additive, that is, the coefficient of the total passage of substances can be spread over each element;

The process of deodorization of vegetable oil is carried out by driving the liquid mixtures of the substance exchange with hot steam. All heat and matter exchange processes take place on the basis

of the laws of mass and heat changes. In these processes, the transition of a substance diffusing in a phase to another phase is carried out by molecular and convective diffusion.

In the process of deodorizing cottonseed oil, the odor and flavoring fatty acids contained in it are extracted by driving with a sharp steam.

A complex mixture of light volatile components that are poorly soluble in water gives the fullness and smell of oils. The literature contains information on the variety of compounds that give the oil its smell and taste. Among them are methyl ketones and methyl carbinols, aldehydes and fatty acids, aliphatic hydrocarbons, alcohols, ethers, etc. /26,38,56,67,68,73/.

These components from pressure depends without various boils to the temperature have

All kinds of leftovers pressures free fat acids to boil temperatures

Residual pressure Rqol mm.rt.st.	The boiling points of the free acid with the number of carbon atoms in the molecule					
	S 8	S 10	S 12	S 14	S 16	S 18
0.1	5934	79.54	98.24	115.67	132.01	147.45
1.0	88.10	109.68	129.72	148.39	165.89	182.42
5.0	113.11	136.02	157.28	177.09	195.66	213.21
10.0	125.45	149.14	171.02	191.42	210.54	228.60

When calculating and carrying out the deodorization process, it is possible to accept the light volatile component with the highest boiling point depending on the pressure, since the components with a lower boiling point volatilize from the oil composition at this temperature. Therefore, in our calculations we get one olein free fatty acid and aldehyde C₉H₁₈O.

Raoul to the law according to ideal gases for light the volatile component is partial pressure, clean of the component that's it in temperature vapors pressure as follows is determined.

$$P(i) = X_j * P_j \quad (1)$$

where $P(i)$ - j is light volatile of the component partial pressure

X_j - in oil j is the mole fraction of volatile volatile component,

P_j - j of the component powder a in the situation vapors pressure.

The process takes go sure temperatures within the limit light the volatile component is clean vapors pressure to determine for, from literature using the following empiric the equation to write can:

$$P_j = B_{0j} + B_{1j} * t \quad (2)$$

B_{0j}, B_{1j} – enter the data work received constant coefficients;

T is light temperature of the volatile component °C. Light amount of volatile component a lot component in the mixture to determine for the following from Eq use can Cottonseed oil deodorization process for this equation as follows is written:

$$X_j = \frac{\frac{a_j}{M_j}}{\frac{a_j}{M_j} + \frac{1-a_1-a_2}{M_4}} \quad (3)$$

in this M_1, M_2, M_4 - cotton oil and light volatile components molecular masses, kg/ kmol;

a_1, a_2 - in oil light volatile component concentration, %.

(1) If we put (2) and (3) into equation a lot component mixture light volatile components partial pressure count equations system formation can:

$$P_1 = (b_0 + b_1 * t) * \frac{\frac{a_1}{M_1}}{\frac{a_1}{M_1} + \frac{a_2}{M_2} + \frac{1 - a_1 - a_2}{M_4}}$$

$$P_2 = (b_2 + b_3 * t) * \frac{\frac{a_2}{M_2}}{\frac{a_1}{M_1} + \frac{a_2}{M_2} + \frac{1 - a_1 - a_2}{M_4}} \quad (4)$$

Above equations system Cramer method our solution in oil light volatile components a_1 Ba a_2 balance concentrations in hardware from the temperature and partial pressures depends without to determine enable gives.

We form the following expressions from the system of equations (4) above by multiplying the denominator of the right side by the left side:

$$P_1(a_1/M_1 - 1 - a_1 - a_2/M_3) = a_1/M_1(b_0 + b_1 * t)$$

$$P_2(a_1/M_2 - 1 - a_1 - a_2/M_3) = a_2/M_3(b_2 + b_3 * t)$$

We form the following expressions from these equations

$$P_1(a_1 M_3 - (1 - a_1 - a_2) M_1) = a_1 M_3 (b_0 + b_1 * t)$$

$$P_2(a_2 M_3 - (1 - a_1 - a_2) M_2) = a_2 M_2 (b_2 + b_3 * t)$$

If we open the parentheses, we get the following result

$$a_1 P_1 M_3 - P_1 M_1 + a_1 M_1 P_1 + a_2 P_1 M_1 = a_1 M_3 (b_0 + b_1 * t)$$

$$a_2 P_2 M_3 - M_2 P_2 + a_1 P_2 M_2 + a_2 P_2 M_2 = a_2 M_2 (b_2 + b_3 * t)$$

We remove the unknowns from the parentheses and the following expression is formed

$$a_1 (P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) + a_1 P_1 M_1 = P_1 M_1$$

$$a_1 P_2 M_2 + a_2 (P_2 M_3 + P_2 M_2 - M_3 (b_2 + b_3 * t)) = P_2 M_2$$

We calculate the determinant D a from the above equations, if the condition D a=0 is not fulfilled, then the desired result can be obtained by solving this system of equations using the Kramer method.

$$P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t) \quad a_1 (P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) + a_1 P_1 M_1$$

$$D a = \frac{a_1 P_2 M_2 + a_2 (P_2 M_3 + P_2 M_2 - M_3 (b_2 + b_3 * t)) * P_2 M_3 + P_2 M_2 - M_2 (b_2 + b_3 * t)}{a_1 (P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) + a_1 P_1 M_1} =$$

$$a_1 P_2 M_2 + a_2 (P_2 M_3 + P_2 M_2 - M_3 (b_2 + b_3 * t)) * P_2 M_3 + P_2 M_2 - M_2 (b_2 + b_3 * t)$$

$$= (P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) (P_2 M_3 + P_2 M_2 - M_2 (b_2 + b_3 * t)) - P_1 P_2 M_1 M_2$$

Also D a_1 and D a_2 s let's find out

$$a_1 (P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) + a_1 P_1 \quad a_1 (P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) + a_1 P_1 M_1$$

$$D a_1 = \frac{a_1 P_2 M_2 + a_2 (P_2 M_3 + P_2 M_2 - M_3 (b_2 + b_3 * t)) * P_2 M_3 + P_2 M_2 - M_2 (b_2 + b_3 * t)}{a_1 (P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) + a_1 P_1 M_1} =$$

$$a_1 P_2 M_2 + a_2 (P_2 M_3 + P_2 M_2 - M_3 (b_2 + b_3 * t)) * P_2 M_3 + P_2 M_2 - M_2 (b_2 + b_3 * t)$$

$$= P_1 M_1 (P_2 M_3 + P_2 M_2 - M_2) - P_1 P_2 M_1 M_2$$

$$= P_1 M_1 (P_2 M_3 + P_2 M_2 - M_2) - P_1 P_2 M_1 M_2$$

$$D a_2 = \frac{P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t) * a_1 (P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) + a_1 P_1 M_1}{P_2 M_2 + a_2 (P_2 M_3 + P_2 M_2 - M_3 (b_2 + b_3 * t)) * a_1 P_2 M_2 + a_2 (P_2 M_3 + P_2 M_2 - M_3 (b_2 + b_3 * t))} a$$

$$= (P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) P_2 M_2 - P_1 P_2 M_1 M_2$$

Received $D a_1$ and $D a_2$ s separately $D a$ Equilibrium concentrations of light volatile components can be calculated by the ratio to, for the first light volatile component

$$a_1 = \frac{D a_1 / D a = P_1 M_1 (P_2 M_3 + P_2 M_2 - M_2 (b_2 + b_3 * t)) - P_1 P_2 M_1 M_2}{(P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) (P_2 M_2 + P_2 M_2 - M_2 (b_2 + b_3 * t)) - P_1 P_2 M_1 M_2}$$

For the second light volatile component

$$a_2 = \frac{D a_2 / D a = (P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) P_2 M_2 - P_1 P_2 M_1 M_2}{(P_1 M_3 + M_1 P_1 - M_3 (b_0 + b_1 * t)) (P_2 M_2 + P_2 M_2 - M_2 (b_2 + b_3 * t)) - P_1 P_2 M_1 M_2}$$

In general, our equation can be written as follows

$$a_j^* = f(p_j^*, t) \quad (7)$$

Conclusion. As can be seen from the resulting system of equations, when driving multicomponent mixtures with acute water vapor, the partial pressures of the components have an effect on the changes in their mutual concentrations.

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