Research on the Performance of Edible Ink-jet Ink

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Abstract

Nowadays, people pay more attention to green printing and environmental protection printing ink, which has become the mainstream in the field of printing, and the recent voice is higher nowadays. Edible ink-jet ink is water-based and environmental friendly and all of its raw materials reach the food sanitation standards. It can be directly printed on the surface of food, medicine and packaging in the non-contact ink-jet printing way. The ink samples were prepared by adding different amount of dye, resin and surface active agent. The viscosity and surface tension of the samples were tested, and the influence of the ink with different performance on the quality of presswork was discussed. The products printed by this ink are innocuous, pollution free and bright in colour. Line quality, field filling quality and dot quality of printing are evaluated and analyzed through a CCD camera-based industrial image analysis system. The result shows that the viscosity and surface tension of edible ink-jet ink have an effect on the quality of printing. Edible ink-jet ink, which is suitable for printing, will be available by changing the amount of resin and surface active agent.

Introduction

We always print simple patterns on the surface of the food or add dye in the food in order to make it look like colorful and beautiful. In resent years, we hope that the patterns will be more complex and the color will be more abundant as diets become more and more diverse. Food surface printing is one of the important means in order to make it come true. Traditional ink is harmful to people's health because it has many organic matters in it, such as gasoline, methylbenzene, alcohol, aromatic compound and so on [1]. When we print on the packaging of the food and medicine with the ink include such substance, we always find that it will contaminate the food and medicine directly or indirectly. So, traditional ink can not be printed directly on the surface of the food and medicine. At present, the technology of developing ink that can be directly used on the surface of food and drug is not mature, and there is only a little product that can be directly used. So, Edible printing ink market has very big development space [2]. Edible ink-jet ink not only has the general common function of printing ink, but also has the characteristic of edible, therefore, it will bring the new market growth point for food and drug industry, printing and packaging industry, and researching this ink has the very vital significance.

Generally speaking, the ink-jet ink performance such as viscosity, surface tension and pH value will affect the quality of ink-jet. In this paper, nine edible ink-jet ink formulas are designed according to orthogonal experimental design of the three factors and the three levels and then the sample is prepared according to the formulas. The printing sample is printed in ink-jet printer and the printing quality is tested, and then the influence of the ink with different performance on the quality of presswork can be discussed. In this way, the best formula of the edible ink can be determined.

Experiments

The raw materials and equipment

The raw materials: Dye, Resin Substitute, Deionized Water, Edible Alcohol, Additives.

Main equipment: SNB-1 Digital Viscosimeter, K100 Surface Tensiometer, Acidometer, Epson me1+ printer, CCD Camera-based Industrial Image Analysis System, Densitometer.

The preparation of the ink sample

Dye, resin substitutes, deionized water, edible alcohol, and additives uniformly are mixed according to the formula, the formula is shown in table 1.Then, the viscosity, surface tension and pH value are measured with the viscosimeter, surface tensiometer and acidometer. Before the ink sample being used, it must be filtered. The ink formula and performance parameters are shown in table 1.

Table 1 ink formula and performance parameters

sample ID	component				performance		
	dye (%)	resin substitute (%)	Alcohol (%)	Additives (%)	surface tension [mN/m]	viscosity [mPa·s]	pH value
1	2-3.5	8	24	0.6	31.95	3.48	6.05
2	2-3.5	8	32	0.4	32.43	3.37	6.17
3	2-3.5	8	28	0.2	32.92	3.44	6.06
4	2-3.5	4	24	0.2	33.01	3.36	6.26
5	2-3.5	4	32	0.6	32.98	3.27	6.27
6	2-3.5	4	28	0.4	31.82	3.42	6.13
7	2-3.5	12	24	0.4	32.02	3.32	6.04
8	2-3.5	12	32	0.2	32.16	3.46	6.20
9	2-3.5	12	28	0.6	33.13	3.19	6.13

The valuation of print quality

The printing sample is printed in Epson me1+ printer with ink sample, the printing sample is shown as Figure 1. Line width is set to 0.1 mm, 0.15 mm, 0.2 mm and 0.25 mm respectively, and dot diameter is set to 0.6 mm, 0.8 mm, 1.0 mm and 1.2 mm respectively. Line width, dot diameter and dot circularity are measured with CCD Camera-based Industrial Image Analysis System, and the line width expansion rate and the dot diameter expansion rate are calculated. The color density of the four color pieces is measured with densitometer and average color density is calculated. The print quality is valuated in four indexes of line width expansion rate, dot diameter expansion rate, dot circularity and color density.

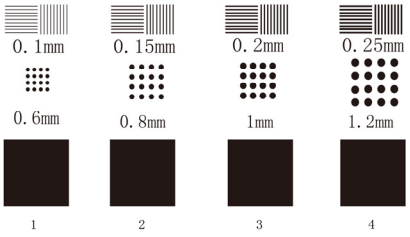

Fig.1 printing sample of edible ink-jet ink

Results and analyses

Line quality

The line width is measured with CCD Camera-based Industrial Image Analysis System, and the line width expansion rate is calculated. The result is shown in table 2. In table 2, W_{11}, W_{12}, W_{13}, W_{14} stand for actual width, R_1, R_2, R_3, R_4 stand for expansion rate of width, and Re1 stand for average expansion rate.

In table 2, W_0 stand for setting width,

$$R_i = \frac{W_1 - W_0}{W_0}(i = 1,2,3,4)$$

It can be calculated according to table 2 that line width expansions are 0.105mm, 0.088mm, 0.059mm and0.108mm respectively when the setting width are 0.1mm, 0.15mm, 0.2mm and 0.25mm respectively. We can draw a conclusion combine with line width expansion rate shown in table 2 that along with the increase of line width, line width expansion and line width expansion rate drop, although there has an unusual increase when setting width is 0.25mm. All of the nine ink samples express good print quality when line width is 0.2mm, but when line width is 0.25mm, line width expansion is larger, this reason may be relate to resolution of printer and paper quality. Line width expansion rate of number 4 ink sample is only 0.19 when the line width is 0.15mm, its print quality is better than other ink samples.

Dot quality

Dot diameter is set to 0.6 mm, 0.8 mm, 1.0 mm and 1.2 mm respectively, dot diameter and dot circularity are measured in the same method as the measurement of line quality, and the dot diameter expansion rate is calculated then. The result is shown in table 3. In table 3, R_5, R_6, R_7, R_8 stand for expansion rate of dot diameter, C_1, C_2, C_3, C_4 stand for dot circularity, R_{e2} stand for average expansion rate of dot diameter, and C_e stand for average circularity.

Table 2 the line width and its expansion rate.

sample ID	0.1[mm]		0.15[mm]		0.2[mm]		0.25[mm]		R_{e1}
	W_{11} [mm]	R_1	W_{12} [mm]	R_2	W_{13} [mm]	R_3	W_{14} [mm]	R_4	
1	0.204	1.04	0.225	0.50	0.268	0.34	0.367	0.47	0.59
2	0.211	1.12	0.278	0.86	0.279	0.40	0.367	0.47	0.71
3	0.197	0.98	0.229	0.53	0.241	0.21	0.347	0.39	0.53
4	0.206	1.06	0.178	0.19	0.268	0.34	0.362	0.45	0.51
5	0.216	1.16	0.246	0.65	0.247	0.24	0.367	0.47	0.63
6	0.207	1.08	0.227	0.52	0.232	0.16	0.357	0.43	0.55
7	0.200	1.00	0.239	0.59	0.253	0.27	0.339	0.36	0.56
8	0.193	0.94	0.270	0.80	0.273	0.37	0.360	0.44	0.64
9	0.211	1.12	0.246	0.64	0.267	0.34	0.356	0.42	0.63

Table 3 dot circularity, dot diameter expansion rate

sample ID	0.6[mm]		0.8[mm]		1.0[mm]		1.2[mm]		R_{e2}	C_e
	R_5	C_1	R_6	C_2	R_7	C_3	R_8	C_4		
1	0.09	1.58	0.06	1.66	0.05	1.40	0.04	1.33	0.06	1.49
2	0.10	1.49	0.07	1.56	0.06	1.46	0.05	1.38	0.07	1.47
3	0.07	1.45	0.04	1.57	0.04	1.36	0.04	1.34	0.05	1.43
4	0.06	1.38	0.04	1.45	0.05	1.40	0.04	1.40	0.05	1.41
5	0.09	1.45	0.06	1.49	0.06	1.37	0.05	1.31	0.06	1.41
6	0.11	1.59	0.07	1.68	0.07	1.56	0.05	1.46	0.08	1.57
7	0.06	1.56	0.05	1.63	0.04	1.45	0.03	1.36	0.05	1.50
8	0.07	1.46	0.05	1.5	0.05	1.39	0.04	1.36	0.06	1.43
9	0.08	1.39	0.06	1.46	0.05	1.37	0.04	1.34	0.06	1.39

In table 3, D_1 stand for actual dot diameter, D_0 stand for setting diameter,

$$R_j = \frac{D_1 - D_0}{D_0} (j = 5,6,7,8)$$

It can be seen from table 3 that diameter expanding rate are relatively small at all places, and with the increase of dot diameter, its expansion rate drop. It can be concluded that the ink sample presents good dot print quality.

Dot circularity refers to the ratio of the dot diameter of all directions, therefore, the dot quality is batter when circularity value is closer to 1. The number 6 ink sample has the highest average circularity value, so its dot quality is very poor, while the number 4 ink sample has a stability circularity value, and the average circularity is also very small. This is a sign that the number 4 ink sample present good dot print quality.

Collesting density

Color density represents collesting density. The color density of the four color pieces is measured with densitometer and average color density is calculated. The result is shown in table 4.In table 4, D_e stand for average color density.

It can be seen from table 4 that the difference between the color densities of the four color pieces is very small, this means that the ink sample is stable in appearance of color. Besides, the density values have reached the related print standards, and theses inks have good fill stability.

Table 4 color density of the four color pieces

sample ID	color density value				
	1	2	3	4	D_e
1	1.31	1.32	1.30	1.30	1.31
2	1.27	1.28	1.29	1.27	1.28
3	1.33	1.35	1.34	1.35	1.34
4	1.29	1.33	1.33	1.32	1.32
5	1.30	1.33	1.33	1.31	1.32
6	1.29	1.31	1.31	1.31	1.31
7	1.17	1.20	1.17	1.20	1.19
8	1.33	1.32	1.33	1.34	1.33
9	1.34	1.33	1.34	1.34	1.34

The comprehensive evaluation of printing quality

Line width expansion rate, dot diameter expansion rate and dot circularity, color density represent line quality, dot quality, field filling quality respectively, and printing quality is comprehensively evaluated with these three quality index in the way of intuitive analysis to orthogonal experiment of multiple index [3]. The weighting factors are 0.6, 0.2 and 0.2 for line quality, dot quality and field filling quality respectively. The analysis result is shown in table 5.In table 5, M_1, M_2, M_3, M_4 stand for membership of width expansion rate, diameter expansion rate, dot circularity and color density respectively, and S stand for comprehensive score.

In table 5,

$$M_{1,2,3} = \frac{index\ \ value - \min imum\ \ value}{\max imum\ \ value - \min imum\ \ value},$$

$$M_4 = \frac{\max imum\ \ \text{value - index value}}{\text{maximum value - minimum value}}.$$

Table 5 analysis table of print quality evaluation

sample ID	R_{e1}	R_{e2}	C_e	D_e	M_1	M_2	M_3	M_4	S
1	0.59	0.06	1.49	1.31	0.40	0.33	0.56	0.20	0.37
2	0.71	0.07	1.47	1.28	1.00	0.67	0.44	0.40	0.79
3	0.53	0.05	1.43	1.34	0.10	0.00	0.22	0.00	0.08
4	0.51	0.05	1.41	1.32	0.00	0.00	0.11	0.13	0.04
5	0.63	0.06	1.41	1.32	0.60	0.33	0.11	0.13	0.43
6	0.55	0.08	1.57	1.31	0.20	1.00	1.00	0.20	0.36
7	0.56	0.05	1.50	1.19	0.25	0.00	0.61	1.00	0.41
8	0.64	0.06	1.43	1.33	0.65	0.33	0.22	0.07	0.46
9	0.63	0.06	1.39	1.34	0.60	0.33	0.00	0.00	0.39

It can be seen from table 5 that the composite scores of number 3 and 4 ink samples are lower than other's, it means that the line width and dot diameter expansion rate and dot circularity value of the corresponding print are lower, while the collesting density is higher. It also means that quality of the print printed with number 3 and 4 ink sample is better.

The establishment of regression equation

The ink performance (including viscosity and surface tension) influence printing quality, so we set up regression equation between ink printing quality and performance in order to discusses the relation between the two. We set the comprehensive score of printing quality into the dependent variable y, and the surface tension and viscosity into the independent variable x_1 and x_2 respectively. We set up multiple linear regression equation with the least square method, and the equation is tested by analysis of variance (ANOVA). The regression equation is shown in Eq. 1, and the ANOVA table is shown in table 6. In table 6, SS stand for quadratic sum, df stand for degree of freedom, MS stand for mean square, F stand for F-test [3].

$$y=13.15-0.27\ x_1-1.19\ x_2. \quad \text{Eq.1}$$

Table 6 ANOVA table

differences source	SS	df	MS	F	significance level
regression	9.86	2	4.93	24.65	very remarkable
residual	1.19	6	0.2	-	-
summation	8.88	8	-	-	-

We look up in table: $F_{0.01}(2, 6) = 10.92$ [3], and $F>F_{0.01}(2, 6)$. We can draw a conclusion that the linear relationship between x1 and x2 is very remarkable, the regression equation is credible.

We standardized partial regression coefficient [3], the result is that: $P_1=0.47$, $P_2=0.36$, $P_1>P_2$ (P_1 and P_2 stand for partial regression coefficient of x_1 and x_2). The result shows that the surface tension has a bigger influence on printing quality compared with viscosity.

Conclusions

(1) The surface tension of the number 3 and 4 ink sample is about 33mN/m, and the viscosity is about 3.4mPa·s. The print printed with these two ink samples display higher level in quality.
(2)The regression equation between ink printing quality and performance is $y=13.15-0.27\ x_1-1.19\ x_2$.
(3) The surface tension has a bigger influence on printing quality.

References

[1] Dai Hong-min. The research and development of the green packaging materials and the developing countermeasures of our country[J]. PACKAGING ENGINEERING. 2004(25). pg. 68-74.
[2] Su Yu-hang. Preparation of Edible Ink and Research of Rheology[J]. CHINA PRINTING AND PACKAGING STUDY..2009(1). pg.47-50.
[3] Li Yun-yan: Experiment Design and Date Processing(Chemical Industry Press, Beijing 2005).

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