Effect of microwave drying on rapeseed's dehydrating characteristics and quality properties

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Abstract

Rapeseed is one of five key oil plants in the world, and main material of edible vegetable oil. But during its harvest and storage, the serious loss was incurred because of acidification and mildew. How to dry rapeseed speedily, effectively and safely has been a key technical problem in practical production. In this research, industrial microwave stove had been chosen as energy source for rapeseed drying. Based on mechanism of rapeseed microwave drying, the effect of microwave drying on rapeseed's dehydrating characteristics and quality properties had been investigated. By a series of experiments, analysis and measurement, it had been proved that: (1) rapeseed of initial moisture content 15%~30% could be dried up to the security storage moisture, by varying ratio of quality-power G, temperature T, heating time t and loading cycle Dc, correspondingly, meanwhile its seeded value had yet been guaranteed; field test showed that quality of its progeny had maintained the same, and its production had risen slightly. (2) microwave drying could activate the rapeseed, and enhance its germinating ability; (3) compared with other drying methods (such as hot-air and far-infrared drying), microwave drying has three stages of acceleration, constant-velocity and deceleration, the constant-velocity phase was the most longest. And drying rapeseed by microwave was innovative, economic and low energy-consumption; (4) microwave, as a radiation energy, could reduce the content of mustard-acid in "821" rapeseed from 42.7% to 22.4%, and glucosinolate from 66.09umol/g to 18.44umol/g. Not only the quality properties of rapeseed had been improved, its comprehensive utilization value had been also enhanced.

Key words: Microwave drying, Rapeseeds, Quality properties, Dehydrating characteristics

1. Introduction

Rapeseed is one of five key oil plants in the world, and is rapidly increasing crops of main material of edible vegetable oil. In general, the initial moisture content of rapeseed is 15%~30% while being harvested, but its safe storage moisture content must be below 9%. The serious loss was incurred by acidification and mildew, because it could not be dried in time after harvest. In practice, rapeseed drying has both natural and artificial drying methods. However, traditional natural drying (wind drying and drying in sun's rays) maybe be affected by natural conditions such as rainy season, and hot air drying have some disadvantages of drying unconformity and difficulty to precisely control moisture content etc. How to dry rapeseed speedily, effectively and safely has been a key technical problem in practical production. Compared with a variety of drying technology, as a new energy technology, microwave drying has unique drying mechanism with both magnetic and electrical characteristics. In this research, microwave drying technology was applied to dry rapeseed by experiments.

2. Materials and methods

2.1 Experimental materials

Black seed "821"-rapeseed, offered by Rape Breeding Center of Huazhong Agricultural University.

2.2 Experimental installations

(1) microwave drying device: consists of RE-630 microwave stove, temperature-control system, supporting system, and holders etc; (2) Drying apparatus: electronic breezing instrument EY3-2A, 101-Ⅲ electro-thermal blasting drying case with controlled temperature range from 50°C~200°C; (3) Else:MP120-1 electronic scale, culture utensil, filter paper, tweezers, etc.

2.3 Determination methods

Water determination with 105°C8h once-through oven-drying method, germination test according to GB5520-85 method, seed's oil content determination according to GB2906-82 method, fatty acid component determination according to GB10219-88 method, glucosinolate content determination with Palladium chloride method.

3. Results and discussion

3.1 Effect on seed's germination percentage

3.1.1 Design and analysis of experimental factors

Through various experimental factors matching, the rapeseed's moisture content was dried by microwave to the requirement of safe storage (under 9%), then the experiment of effect on germination percentage was carried out, the experimental factor levels were showed in Table1.

Table1 Experimental Factor Level Table

levels	ratio of quality-power /G/W/g	initial moisture content /W/%	temperature /T/°C	load cycle /Dc/min	time /t/min
upper level (+1)	0.35	30.0	65	15	90
zero level (0)	0.30	22.5	60	10	70
lower level (-1)	0.25	15.0	55	5	50
varying range	0.05	7.5	5	5	20

The experiment indicated that the factor order was initial moisture W, ratio of quality-power G, time t, interactive term of initial moisture content and ratio of quality-power W × G, temperature T, interactive term of initial moisture content and time W × t and load cycle Dc. The regression equation drawn from the experiment showed the function formula of germination percentage and other factors as:

$$F = 102.66 + 1.283W + 40G + 0.1t - 0.275T - 0.125D_C - 4.33W \times G - 0.0083W \times t$$

The notability test indicated that the regression formula was notable. Based on the result, with gradient method of once-through regression orthogonal design, the optimal area was obtained: initial moisture content W=11.25%~26.55%, ratio of quality-power G=0.23W/g~0.33W/g, temperature T=53.69°C~63.69°C, time t=47.34min~87.34min, load cycle Dc=4.54min~14.54min.

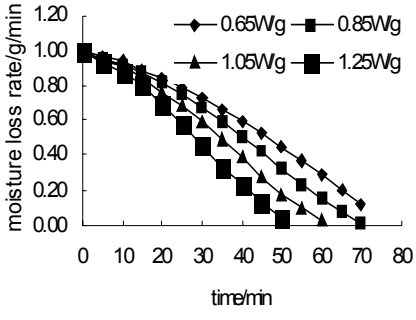

Figure 1.Result of Time and Dehydration Speed at Varying Ratio of Quality-Power

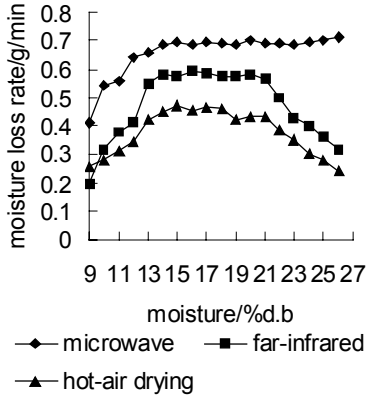

Figure 2. Result of Moisture and Dehydrating Speed at Varying Drying Methods

3.1.2 Experiment of germination potential and germination percentage

According the optimal area of experimental factors drawn from orthogonal experiment design, drying experiment was carried out under condition of 0.25W/g, 26% and 60°C, and germination experiment was carried out immediately after the dying experiment. The experiments showed that the average germination potential of rapeseed processed by microwave was 96.5%, up 4.25 percentage point than 92.25% of without microwave processing. And the germination experiment showed the seedling height in the fifth day was higher than of without microwave processing. During the microwave drying, the seed energy was enhanced because of a suitable microwave radiation dose's incentive acceleration to seed energy. Meanwhile the germination percentage of microwave processed seeds was 95.5%, almost the same as of without microwave processing 95.75%, in accord with the germination percentage demand of national standard.

3.2 Experiment and analysis of dehydration characteristics

Water and vapor diffusion exists in materials during microwave drying. The following data transformation was taken before experiment: moisture content W was transformed to water percentage WR through formula WR = [W-We] / [W_0-W_e], in it W is seed moisture content, W_0 is seed initial moisture content, W_e=11.45rh$^{0.715}$, rh is relative humidity. Figure 1 is the curve of varied ratio of quality-power and water dehydrating percentage to time, it showed that in the initial stage of drying the drying speed increased along with the ratio of quality-power, on the other hand, in the later stage, the drying speed tended to be unvaried, and every curve demonstrated that, with constant initial water content, microwave drying rapeseed was a limited diminution process.

Considering the feasibility of practical production, further comparing with far-infrared and hot-air drying, the dehydration characteristics of different drying method were obtained and shown in Figure 2. It may be drawn from the curves that in the constant speed stage the seed moisture percentage distribution was different correspondingly to the three drying methods. In microwave drying, most dehydration occurred in the constant speed stage, indicating that microwave drying is of the strongest drying ability, far-infrared drying the second, hot-air drying the weakest. The power calculation indicated that to dry seeds of the same quality, hot-air drying consumed the most power, microwave drying consumed the least power, infrared drying between them.

3.3 Effect on seed qualities

Table 2 Result of Effect of Microwave Drying on Rapeseed Quality

	repeat times	concentrated fat	fat acid							glucosinolate
			palmic acid	stearic acid	oleic acid	linolic acid	linolenic acid	diluted peanut acid	erucic acid	
natural drying	1	41.75	3.00	1.02	20.98	12.15	7.46	12.12	42.84	64.2792
	2	41.67	3.10	1.15	21.08	12.34	7.76	11.92	42.56	67.7980
	average	41.71	3.05	1.08	21.03	12.48	7.72	12.02	42.72	66.0986
microwave drying	1	42.66	4.27	1.90	40.07	18.08	7.24	7.03	22.41	18.9025
	2	42.56	4.27	1.97	39.99	18.00	7.27	6.99	22.44	17.9792
	average	42.61	4.26	1.94	40.03	18.10	7.26	7.01	22.42	18.4422

Table 3 Rapeseed Offspring Properties in Both Processing Ways

processing manners	plant height/cm	ramifying position/cm	effective ramifications	seed of single plant /num.	thousand-grain weight/g	output/kg	erucic acid /%	glucosinolate /umol/g
microwave drying	174.6	602	8.4	306.9	3.15	126.06	39.46	69.913
natural drying	169.1	55.6	7.6	279.9	3.09	118.6	40.24	78.64

Under condition of ratio of quality-power 0.25W/g, initial moisture content 26%, temperature 60°C and load cycle 5min, microwave drying and natural drying were carried out simultaneously, though determination and analysis, the effect on rapeseed qualities was obtained showed as Table 2 and Table 3. It may be drawn from the effect of microwave drying on rapeseed characteristics that rapeseed qualities had been improved by microwave processing under proper conditions, among the improved qualities, the content of erucic acid and glucosinolate reduced, oleic acid content increased, the nutritional value was enhanced, all of the above indicated that advantageous variation had occurred. The offspring of microwave processed rapeseed showed superior properties than of natural drying. It is because that microwave is a kind of electro-magnetic wave, has both effects of magnetic field and electricity field. Microwave processing materials is a physical process without causing rapeseed gene mutation. But microwave has physiological effect on rapeseed, the degree of effect and the pros and cons depend on radiation dose and coordinated technological measure.

4. Conclusion

1. According to various rapeseed initial moisture contents (15%~30%), selecting suitable ratio of quality-power (0.25W/g), setting corresponding temperature range (50°C~60°C) and drying time, rapeseed may be dried to the requirement of safe storage (under 9%). The result demonstrated that microwave drying rapeseed is feasible.

2. Microwave drying can activate seed energy, enhance seed germination potential, the average germination potential of microwave processed rapeseed is 4.25% more than of rapeseed without microwave processing. The main characters of microwave processed rapeseed were better than of natural drying.

3. The quality of rapeseed can be improved by irradiation of a certain dose of microwave as a kind of radiation energy. A comparison of microwave drying and natural drying indicated that microwave drying can enhance rapeseed nutritional value through decreasing erucic acid content, increasing oleic acid and linonic acid content, and reducing the glucosinolate content also.

4. Compared with constant-temperature hot-air drying and far-infrared drying, microwave drying is unique for the biggest dehydrating speed in constant speed stage, strong dry ability, low power consumption and good economic when drying rapeseeds of same quality and initial moisture content.

5. Microwave drying may adapt to various technological parameters by precisely controlling the moisture content and microwave output power through using a temperature controlling system. In order to enhance the dry efficiency in practical production and operation, hot-air drying and microwave drying may be combined, and continuous production may be realized through setting the length of conveyer belt and technological process.

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