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Drying of Black Pepper (*Piper nigrum* L.) Using Solar Tunnel Dryer

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ABSTRAK

Lada hitam (Piper nigrum *L.*) *dikira sebagai raja di kalangan rempah-ratus. Negeri Kerala sahaja menyumbang kira-kira 97% daripada jumlah pengeluaran lada di India. Sebanyak 75 jenis lada ditanam di kawasan-kawasan berbeza di negeri tersebut. Kepedasan dan aroma adalah kualiti lada paling penting, yang merujuk kepada oleoresin dan minyak volatil. Kualiti lada banyak bergantung kepada kaedah-kaedah selepas dituai. Satu kajian yang meluas ke atas kejadian lada hitam dan pengeringan telah dikendalikan. Hanya pengeringan terbuka cahaya matahari secara konvensional dilaksanakan di negeri Kerala. Sampel-sampel lada yang dikumpul daripada pelbagai lokasi dikeringkan dalam pengering terowong yang diimport (Jerman) dan kualiti rempahnya dibanding dengan sampel komersial. Penceluran dilakukan sebelum setiap pengeringan. Standard kualiti ASTA (Pertubuhan Perdagangan Rempah-ratus) dan Agmak diuji ke atas sampel komersial dan sampel yang dikeringkan menggunakan pengiring terowong. Signifikan kepelbagaian kualiti lada kedua-duanya diketahui. Kira-kira enam hari diambil untuk pengeringan sampel-sampel komersial manakala sampel-sampel pengeringan terowong hanya mengambil masa 8 jam. Kandungan piperin dalam sampel komersial hanya 4% berat sementara berat sampel pengeringan adalah 4.5%. Sampel yang dikeringkan dalam terowong mempunyai kualiti fizikal yang lebih baik berbanding sampel komersial seperti yang dispesifikasi oleh ASTA. Pembaikan kualiti dan pengurangan masa pengeringan menjadi bukti kepada sampel yang dikeringkan dalam terowong solar. Pengering terowong solar yang diimport dari Jerman sangat sesuai untuk pengeringan lada hitam. Keadaan optimum diperlukan untuk pengeringan rempah-ratus ini boleh diterangkan. Analisis-analisis kualiti psikokimia membuktikan bahawa pengeringan yang diuji untuk pengeringan lada tersebut adalah cukup efisien bagi menghasilkan lada yang berkualiti untuk dieksport.*

ABSTRACT

Black pepper (Piper nigrum *L.*) *is considered to be the king among the spices. The State of Kerala alone contributes about 97% to the total pepper production in India. Seventy-five pepper varieties are cultivated in different parts of the country. Pungency and aroma are the most important qualities of pepper, which is attributed to oleoresin and volatile oil respectively. The quality of pepper is very much dependent on the post-harvest methods. An extensive survey on the occurrence of the black pepper and drying methods were conducted in this investigation. Only conventional open sun drying is practised in the State of Kerala. Pepper samples collected from different locations were dried in an imported tunnel dryer (Germany) and quality of the tunnel-dried spice was compared with commercial samples. Blanching was done before each drying. ASTA (American Spice Trade Association) and Agmark quality standards were tested on the tunnel dried and commercial samples. Significant variations of pepper quality between sampling stations were noticed. Approximately 6 days were taken for the drying of commercial samples whereas in solar tunnel dryer it took only 8 hours. Piperine content in commercial samples was only 4% by weight while in dryer samples it was 4.5% by weight. Tunnel dried samples had better physical quality than the commercial samples as specified by ASTA. Quality improvement and reduction in drying time were evident for the solar tunnel dried samples. Solar tunnel dryer imported from Germany is highly suitable for black pepper drying. Optimum conditions required for the drying of this spice could be defined. Physico-chemical quality analyses proved that the dryer tested for the pepper drying is efficient enough to produce pepper of export quality.*

INTRODUCTION

The enticement of spices prompted explorers like Columbus and Vasco da Gama to undertake hazardous sea journeys to discover India, 'the land of spices'. Black pepper is considered to be the king of spices. This spice is the dried mature but unripe fruit of *Piper nigrum* L. The State of Kerala alone contributes about 97% of the total production of pepper in India (Ravindran *et al.* 1997). Black pepper is believed to have originated in the evergreen forests of Western Ghats of Peninsular India (Ravindran and Nair 1984). Out of seventy-five pepper varieties cultivated in the country *Panniyur I* is considered to be the most successful variety of the pepper. Major commercial pepper grades exported from India are Malabar garbled, Tellichery garbled and Aleppey garbled (Anon 1997).

Black pepper requires a humid climate with adequate rainfall and temperature for its growth (Gangadharan 1998). *Piper nigrum* L. is mostly dioecious in its wild state while most of the cultivated types are bisexual. Cultivated black pepper is self-pollinated, the mode being geitonogamy aided by rainwater or dewdrops (Ravindran *et al.* 1997). After flowering, six to eight months maturity is needed for harvesting. Harvesting is done during the months of December to February for low land crops and January to April for hill grown pepper.

Post-harvest technology has a tremendous role in the quality improvement of spices (Pruthi 1993). In the case of pepper, spikes are removed from the vines and they are kept as such for a day for despiking. The most common pre-treatment before drying adopted in Kerala and the Karnataka States of India is blanching (Anonymous 1997). The blanched berries require only 2 days for drying in the sun (Pruthi 1992). Blanching minimizes microbial contamination and thus gives a more hygienic product. After blanching, the pepper is sun dried on mats or clean concrete floors. Sun dried pepper berries take 4-5 days for proper drying, depending upon the climatic conditions (Krishnamurthy *et al.* 1993). Sun drying has several limitations. Therefore the use of artificial dryers becomes essential (Shukla 1983). The possible alternate drying technologies are infrared drying, conduction drying, heated air drying, desiccated air drying and refrigerated air drying for agricultural commodities (Shukla and Patil 1992). The use of solar dryers in comparison with open sun drying gave better quality products with lesser drying time (Patil 1989). Kamaruddin *et al.* (1994) have developed a method for the drying of pepper using solar energy. Pruthi (1989) had shown a drying time of 8 hours for 30-40 tones of pepper when dried in a mechanical dryer imported from Holland.

To improve the overall quality of pepper, a solar dryer and some additional appropriate technologies were used to produce pepper of a high microbiological standard, deep black colour and low humidity (Ahlert *et al.* 1997). The quality of black pepper is assessed by its aroma and pungency retained after drying. The pungency of pepper is due to the presence of piperine. According to Mathulla *et al.* (1996) the main pungent principle is piperine which is 2-trans, 4-trans piperidine amide of piperic acid. Piperine from black pepper is a bioactive material, which when consumed with other drugs gives improved effectiveness (Mathew 1998). In the present investigation, black pepper collected from different parts of Kerala are dried in a solar tunnel dryer imported from Germany. Quality improvement and reduction in drying time observed are discussed in this paper.

MATERIALS AND METHODS

Kerala is the southernmost State of India, which occupies an area of 38,863 sq.km, about 1.3 percent of the country. This state is located between 8°18' and 12°48' North latitude, and 74°52' and 77°22' East longitude. Pepper is cultivated in Kerala along the highlands, midlands and lowlands. Sampling locations were identified from all these altitudinal zones. Kalady (lowland), Ezhattumugham (midland) and Kumili (highland) were the sampling sites. Investigation started with an extensive survey in order to understand the post-harvest technologies prevailing in the sampling stations. Freshly harvested 60 kg of black pepper samples were collected thrice from the three sampling stations during the months of January, February and March 1999. Each pepper sample consisted of an assorted mixture of cultivars such as *panniyur I, karimunda, kalluvalli, vellikkinnan, balankotta* and *aimpirian*. The samples were collected in clean polyethylene bags and transported to the research centre within three hours of harvesting. Pepper samples were heaped for one day in a clean room. After that, despiking was done manually. Blanching was done by immersing the pepper samples in boiling water for exactly one minute with the help of a perforated bamboo basket. Samples were temporarily spread on a clean mat for the draining of excessive water and uniform colouration. Initial moisture content and wet weight of the produce were recorded.

Solar Tunnel Dryer

The solar tunnel dryer was developed at the Institute for Agricultural Engineering in the Tropics and Sub-tropics of Hohenheim university, Germany. It consists basically of a plastic foil covered flat plate solar air heater, a drying tunnel and two small axial flow fans (Esper and Muhlbauer 1996). To simplify the construction and to reduce the production costs, the solar air heater is connected directly to the drying tunnel without additional air ducts (*Fig. 1*). Both the collector and drying tunnel are installed on concrete block substructures to ease loading and unloading of the dryer. The entire floor of both solar air heater and the drying tunnel consists of plastic foam sandwiched between two metal sheets with a groove and tongue system, have a length of 17 meters (10 m for tunnel and 7 m for heater) and 2 meters breadth. The entire bottom surface of the solar air heater of the dryer is coated with black paint (90% absortivity). In the solar tunnel dryer, the crop is spread out on a wire mesh placed 20 mm above the floor, which is covered with a plastic net aimed to sieve the smaller dust and dirt through the holes during drying. The solar air heater and the tunnel are covered with a transparent uv stabilized PE plastic foil 0.2 mm in thickness with a transmissivity of 92% for visible radiation. Two axial flow fans are incorporated in the sandwiched substructure at the back of the air inlet of the solar air heater to suck ambient air into the collector. The capacity of the tunnel ranges from 60 kg to 200 kg wet fruits depending upon the size of the fruit and thickness of the spreading layer. The solar tunnel dryer was successfully tested under field conditions, in about 30 countries with different climatic conditions, drying numerous agricultural commodities, fish and meat. This solar dryer is installed at the Botany research centre of Sacred Heart College and all the drying experiments were conducted in this dryer.

Drying of Pepper

Blanched berries were spread in one fruit thickness on a clean perforated mat kept 2 cm above the surface inside the solar tunnel dryer. No overlapping and clustering of berries were allowed. The dryer system was closed by steering down the pedal carrying the PE foil roof and allowing the samples to dry. Drying started at 9 a.m. in the morning. Temperature and relative humidity of the dryer and ambient air were recorded in two hour intervals from 9 a.m. to 5 p.m. Mercury thermometer and an air guide (USA) instrument were used for the measurement of temperature and relative humidity respectively. The intensity of solar radiation was measured at the roof of the dryer using a pyranometer. All the readings inside the dryer were taken from three distinct zones viz. the junction of solar air heater and drying tunnel, middle of the tunnel just above the crop and at the outlet of the dryer. To provide more or less uniform drying conditions and to develop uniform colour the berries were mixed and respread at every one-hour interval within the dryer. After the completion of drying the pepper, berries were sifted along with the plastic net to settle down the pinheads and other small materials from the dried produce. Dry weights of the samples were taken and amount of spice recovery was calculated. Random subsamples were taken in triplicate for the physico-chemical quality analyses. Analyses were carried out at the Quality Evaluation and Upgradation Laboratory of Spices Board, Cochin and at the Botany research centre of Sacred Heart College, Thevara, Cochin according to the National and International Standards. Physical quality parameters specified by ASTA (1998) and Agmark (Anonymous 1996) were analysed. Chemical quality parameters such as moisture, volatile oil, oleoresin, crude fibre, piperine and total ash were determined using ASTA (1997) methods. Commercially available conventionally dried pepper samples were also collected from the same sampling stations from where the wet samples were collected for solar tunnel drying. These samples were also analysed for the same parameters adopted for tunnel-dried samples for a comparative evaluation of quality. The data collected through the experiments were computed statistically (Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

The survey conducted during this study revealed that agricultural practices, method of harvesting and post-harvest technologies employed in all the three sampling stations were the same for pepper. Single cultivar plantations of black pepper are not available in the sampling areas. In most cases different pepper cultivar produces will be collected and assorted before drying. Only the conventional sun drying method is prevalent in Kerala for pepper drying. The survey revealed that commercially available pepper samples are dried in 5 to 7 days.

Variations in temperature, relative humidity and solar radiation measured inside the dryer during the drying of pepper samples collected from three different sampling stations are given in *Figs. 2, 3* and *4*. Temperature and relative humidity showed an inverse relationship as in the histograms. Minimum solar radiation obtained during the drying period was 15 mA (318 W/m^2), and 43 mA (822 W/m^2) was the maximum. No sudden fluctuation of the solar radiation was noticed during the drying. Maximum and minimum temperatures noticed inside the dryer were 70°C and 34°C respectively, whereas during the drying period ambient air showed a maximum temperature of 41°C and a minimum of 30°C. Relative humidity noticed in the dryer was always less than that of the ambient air. During the drying period ambient air showed a relative humidity between 34% and 60%. Moisture content present in the pepper before and after drying, drying time taken, and spice recovered after drying are represented in Table 1. Only 33.7% of the wet samples were recovered after drying. Drying of samples was completed within eight hours. The results of the physico-chemical analyses done for the tunnel dried and commercially available samples are given in Tables 2 and 3. Analysis of variance between different sampling stations showed strong significance for all the parameters analysed. ANOVA of tunnel dried and commercial samples was also found significant for all attributes studied. In the present investigation pepper samples collected for drying from different sampling stations were assorted in nature. According to Sumathikutty *et al.* (1989) pepper of commerce is a mixture of all the cultivars. In all the drying experiments, pepper was spread inside the dryer in one fruit thickness to reduce the drying time.

Sodha *et al.* (1985) reported that for open sun drying the grain layer thickness should not be more than 5 cm. In Sri Lanka, drying is carried out after immersing the berries in steaming hot water for about 2-3 minutes and dried in a hot air dryer at 47°C to 51°C for 36 hours (Abeysinghe 1982). Before tunnel drying the pepper samples were dipped in boiling water for one minute in the present investigation. However according to Jacob *et al.* (1985) blanching improves the colour but affords pepper fruits depleted of significant quantum of volatiles. After drying, pepper samples showed a size decrease. Pepper after drying shrinks in size and wrinkles are formed in the skin (Thomas and Gopalakrishnan 1992). For black pepper fully mature green berries were dried conventionally in the open sun, which took four-five days to get pepper of commerce (Patil 1989). In the present investigation, all the samples were dried within eight hours in the dryer. Open sun drying is widely practiced in tropical countries but the method is extremely delayed, weather dependent and has the problem of contamination,

TABLE 1
General observations during the drying of black pepper in the solar tunnel dryer and commercial samples

Sampling Stations	Percentage Moisture Content (Before drying)	Spice Recovery (%)	Percentage Moisture Content (After drying)		No. of days for optimum drying	
			Commercial Sample	Solar Dryer	Commercial Sample	Solar Dryer
Kalady	77.7	34.7	12.4	12.4	6	8 hrs
Ezhattumugham	78.1	32.3	13.6	10.4	7	8 hrs
Kumili	76.7	34.2	14.4	10.8	5	8 hrs

TABLE 2
Result of quality analyses of black pepper after drying in solar tunnel dryer from different location

Parameters	Kalady		Ezhattumugham		Kumili	
	Mean*	S.D.	Mean*	S.D.	Mean*	S.D.
Extraneous matter% by wt.	0.28	±0.03	0.14	±0.03	0.11	±0.06
Light berries ,,	0.90	±0.16	5.00	±1.60	0.60	±0.08
Pinheads ,,	0.10	±0.05	0.00		0.00	
Size above 4.25mm ,,	82.9	±2.37	82.5	±1.08	91.4	±2.30
Size above 4.75mm ,,	12.3	±5.20	10.8	±1.40	6.10	±1.30
Moisture ,,	12.4	±1.40	10.4	±0.14	10.8	±0.16
Volatile oil ,,	2.00	±0.00	2.30	±0.22	2.17	±0.02
Piperine ,,	4.30	±0.22	4.70	±0.16	4.50	±0.41
Oleoresin ,,	8.40	±0.14	8.20	±0.14	6.50	±0.42
Crude fibre ,,	11.3	±0.96	12.3	±0.24	12.2	±0.08
Total ash ,,	5.00	±0.82	4.80	±0.45	4.30	±0.16
Whole insects dead % by count	0.00		0.00		0.00	
Insect defiled/infested % by wt	0.00		0.00		0.00	
Excreta mammalian % by mg/lb	0.00		0.00		0.00	
Mould % by wt	0.00		0.00		0.00	

* All values are means of triplicate samples

TABLE 3
Result of quality analyses of commercial black pepper samples collected from different locations

Parameters	Kalady		Ezhattumugham		Kumili	
	Mean*	S.D.	Mean*	S.D.	Mean*	S.D.
Extraneous matter % by wt.	0.18	±0.02	0.49	±0.16	1.58	±0.06
Light berries ,,	1.20	±0.10	6.30	±0.33	2.21	±0.03
Pinheads ,,	0.00		0.90	±0.16	0.54	±0.03
Size above 4.25mm ,,	78.7	±0.58	78.8	±1.28	94.0	±2.89
Size above 4.75mm ,,	19.2	±0..14	23.3	±2.58	5.22	±0.10
Moisture ,,	12.4	±0.30	13.6	±0.42	14.4	±0.57
Volatile oil ,,	1.17	±0.02	1.50	±0.28	2.17	±0.15
Piperine ,,	4.07	±0.06	4.29	±0.03	3.98	±0.06
Oleoresin ,,	7.03	±0.06	8.65	±0.07	8.26	±0.02
Crude fibre ,,	9.41	±0.08	10.5	±0.08	11.5	±0.05
Total ash ,,	4.65	±0.08	4.90	±0.71	4.55	±0.15
Whole insects dead % by count	0.00		0.00		7.00	±1.63
Insect defiled/infested % by wt	0.00		0.15	±0.04	0.39	±0.06
Excreta mammalian % by mg/lb	29.0	±0.82	0.00	0.00		
Mould % by wt	1.80	±0.02	6.40	±0.30	4.45	±0.33

* All values are means of triplicate samples

infestation and microbial attack (Kachru and Gupta 1993; Ratti and Mujumdar 1997). Disadvantages of direct sun drying can be overcome by the use of solar dryers (Blumenberg *et al.* 1997). Maximum temperature inside the dryer during the solar tunnel drying was 70°C. Each spice has a critical dehydration temperature and this temperature can vary with the end use for which it is put (Shankaracharya and Natarajan 1975). According to Grupp *et al.*(1995) red pepper and green pepper when dried in solar tunnel dryer showed excellent results but needed an alert operator to avoid over drying.

All the results of the present investigation have shown that the method of drying determines the quality of the spice. The quality of black pepper is largely determined by berry size, colour, light berry content, damaged berries, moisture content, foreign matter, insect infestation, animal excreta and microbial load (George 1996). In the present investigation statistical analyses of attributes studied showed significant variation between the samples collected from different sampling locations. Varietal diversity is one of the principal components of diversity in black pepper (Ravindran *et al.* 1997). The samples, both the tunnel dried and commercial samples collected for the study, belonged to different varieties. In black pepper variation in oleoresin, piperine and essential oil contents were noticed among the different cultivars (Ravindran and Nair 1984; Zacharia 1998). The quantity and quality of oleoresin depend to a great extend on the geographical origin of the spice (Shankarikutty *et al.* 1982). Mishra (1998) observed the variation in quantity of oil in different varieties of pepper, which is responsible for difference in aroma and taste. Black pepper dried in solar tunnel dryers was hygienic and performed high quality over commercial samples. All the tunnel dried samples were qualified for ASTA and Agmark standards of pepper quality. A total quality improvement such as colour, appearance, aroma and pungency was achieved through the drying of pepper in solar tunnel dryers. Moreover, it is possible to ensure the quality of spice produced under the optimum conditions of the dryer.

CONCLUSIONS

From the results of the study the following conclusions can be drawn:-

- The solar tunnel dryer is suitable for black pepper drying.
- Physico-chemical qualities of the tunnel-dried samples are significantly high over the commercial samples.
- Optimum drying conditions for the pepper drying can be predicted.
- There is a significant variation of pepper quality attributes depending upon the cultivar and place of growth.
- The importance of post-harvest technology to improve the export quality of pepper is confirmed.

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