DRYING AND PRETREATMENTS AFFECT THE NUTRITIONAL AND SENSORY QUALITY OF OYSTER MUSHROOMS

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

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ABSTRACT

The effect two drying treatments (solar and oven), three blanching treatments (no blanching, water and steam), and four chemical treatments (no chemical, lemon juice, vinegar and potassium bisulfite) on oyster mushroom quality was investigated. Sensory quality, total phenolics, total flavonoids, ergothioneine, oxygen radical absorbance capacity, moisture, mold infestation, mineral content and protein were evaluated. Among the un-blanched samples, those that were treated with lemon juice and those without any chemical pretreatment before drying had better appearance, flavor and were more generally acceptable than those with vinegar and potassium bisulfite treatments. However, when blanching was done, samples treated with potassium bisulfite had superior sensory quality when compared to lemon juice, vinegar and the control. Solar drying caused more browning when compared to oven drying. The combination of water blanching with either lemon juice or vinegar treatments before drying resulted in higher flavonoid content. Lower ergothioneine and total phenolic compounds were observed in blanched mushrooms compared to the un-blanched ones. Total flavonoids were highest in the water blanched samples and least in the un-blanched ones. Among the chemical pretreatments, higher total phenolic compounds were observed in vinegar and potassium bisulfite treated samples. Blanching resulted in lower K, Mg, Na, S and P content when compared to the control. Mineral nutrients varied with chemical pre-treatments. Blanching followed by either lemon juice or no chemical treatment resulted in high mold infestation. Among the un-blanched samples, those treated with vinegar had the least mold infestation. Drying method, blanching, and chemical pretreatments affected oyster mushroom quality hence a need to carefully select preservation methods so as to minimize quality compromise.

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CHAPTER 1. GENERAL INTRODUCTION

Oyster mushrooms are the second most widely grown mushroom in the world (Sánchez, 2009), valued for their nutritional, medicinal and income contribution. Oyster mushrooms contain most essential amino acids, carbohydrates, minerals, and fiber (Mandeel et al., 2005). Oyster mushrooms also contain antioxidants that have been shown to alleviate oxidative stress in studies done *in vitro* (Fu and Shieh, 2002; Selvi et al, 2007) and *in vivo* (Jayakumar et al., 2006) and thus can contribute to the management or prevention of diseases associated with oxidative damage. While they contain all these beneficial components, oyster mushrooms are low in calories, fat and Na.

Mushroom cultivation can improve livelihoods in poor communities by providing highly nutritious food and possibly generate income (Marshall and Nair, 2009). Oyster mushrooms are especially suited for this role as they do not require high expertise, or high capital investment and production can be easily integrated with other on-farm or household activities. Oyster mushrooms can grow on about 200 different types of lignocellulosic materials (Poppe, 2004) hence there is a wide range of inexpensive locally available materials that can be used for their cultivation. Spent compost can be recycled to improve soil fertility or used as animal feed (Marshall and Nair, 2009). Mushrooms thus have a high potential for integration into local food systems.

Oyster mushrooms are highly perishable and post-harvest preservation is often associated with a compromise in quality (Bano and Rajarathnam, 1988). Fresh mushrooms have high water content, high enzymatic activity and hence are highly perishable (Barros et al., 2007). Continued physiological activity in fresh mushroom tissue may results in quality losses.

Oyster mushrooms have the shortest shelf-life of cultivated mushrooms (Marshall and Nair, 2009). Optimum growth of different oyster mushroom strains and species ranges between temperatures of 25-35^{o}C (Kong, 2004), hence efficient production may only be limited to warm seasons. Appropriate preservation methods would allow for consumption throughout the year, ease of transportation and use of mushrooms as ingredients for other processed foods.

Dehydration is the oldest method of mushroom processing (Rama and John, 2000) that can extend shelf life for to up to a year (Bano et al., 1992). Solar drying, although characterized by several challenges, remains the most inexpensive method of food dehydration (Cohen and Yang, 1995). The appearance, organoleptic and nutritional quality of fresh foods usually changes during post-harvest processing and storage. Sensory quality is a major determinant for consumer acceptability and market value. Pretreatments such as blanching and several chemical preservatives like as ethylene-diamine-tetra-acetic acid (EDTA), citric acid and potassium metabisulphate (KMS) can be used to help preserve some sensory characteristics when drying mushrooms (Coşkuner and Özdemir, 2000). However, some of these pretreatments have been shown to compromise the nutritional quality of the mushrooms, possibly by nutrient leaching (Gothandapani et al., 1997).

Current research has focused on preservation methods that focus on either sensory or nutritional qualities without trying to optimize both simultaneously. Research on oyster mushroom preservation has been geared towards improving commercial processing. To fully exploit the potential of oyster mushroom at household level especially in resource limited communities, there is need for simple and affordable post-harvest preservation methods that optimize the quality of oyster mushroom. This research aims to determine the effects of various pretreatments and drying methods on the nutritional composition, antioxidant properties, and

sensory quality of oyster mushrooms. The focus is on preservation methods that are easily adoptable at household level even with resource limitations. Knowing the effects of drying and pretreatments on the nutritional and anti-oxidant properties will empower the producers, processors and consumers with knowledge of whether there is nutritional and antioxidant activity comprise from dehydration of oyster mushroom and the associated pretreatments. Even in cases where production is limited to certain times of the year, preservation will allow for shelf life extension and thus the possibility of mushroom consumption throughout the year. The knowledge of simple and easily adoptable post-harvest preservation methods will thus promote mushroom production.

1.1. Overall Objectives

1. To determine some nutritional components of oyster mushrooms under different pretreatments and dehydration methods.
2. To determine the antioxidant content and activity of oyster mushrooms under different pretreatments and dehydration methods.
3. To determine the sensory quality of oyster mushroom under different pretreatments and dehydration methods.

1.2. Hypothesis

Drying methods and pretreatments will affect the nutritional, sensory and antioxidant quality of oyster mushroom due to physical and chemical changes that occur during processing.

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CHAPTER 2. LITERATURE REVIEW

2.1. Mushroom Classification

Mushrooms are classified under the kingdom Mycota, and division Eumycota (Kuo, 2003). Basidiomycota is the phylum that contains most edible fungi with *Cantherelles, Hymenochaetales, Phallales, Boletales and Agaricales* being the most important orders. Oyster mushrooms belong to the *Pleurotus* genus with several species that include *P. ostreatus*, *P. sajor -caju,* and P. *florida*.

2.2. World Overview

Approximately 12,000 fungi species are considered to be mushrooms with about 2,000 of these having varying degrees of edibility (Chang, 1999). An estimated 200 species of edible mushrooms are commonly collected from the wild while about 100 species are cultivated (Boa, 2004). The mushroom industry has been growing over the years and is of considerable economic importance with an estimated worth of 40 billion dollars in 2005 (Chang, 2006). China is the world leading producer of mushrooms producing 47% of total mushrooms (Harsh and Joshi, 2008) and 85 % of oyster mushrooms (Royse, 2003), but the United States and Germany are the leading consumers (30% and 17% respectively) (Harsh and Joshi, 2008). Even though fresh mushrooms are preferred, due to their high perishability, most traded mushrooms are processed. Mushroom cultivation and consumption is encouraged for sustainable livelihoods in developing countries (WHO, 2007). Oyster mushrooms are especially suited for this role as they are easy to grow and require minimal capital investment.

2.3. Oyster Mushroom Nutrition

2.3.1. Protein

Protein is more often the limiting nutrient in diets and thus mushrooms are commonly valued for their protein contribution, especially in resource limited communities (Mshandete and Cuff, 2007). The protein content of oyster mushroom has been reported to range between 30 and 40% (dry weight basis) (Mandeel et al., 2005) which compares well with other protein rich foods. Protein content in food is often estimated by applying a conversion factor to the total measured nitrogen in the food. Although this is a highly acceptable method, use of variable conversion factors make comparison of results from different workers difficult (Mattila et al., 2002). Also, fungi are known to contain some non-protein nitrogen (23-40%) which is found in the chitin cell wall, free amino acids and nucleic acids, thus estimations by the commonly used conversion factor of 6.25 are rendered inaccurate. A conversion factor of 4.97 to be specifically used for oyster mushroom was obtained by Mattila et al. (2002).

Mushrooms contain most essential amino acids with higher contents of sulfur containing amino acids when compared to vegetable protein sources (Mattila et al., 2002). Mushrooms are also rich in lysine (Rai and Arumuganathan, 2008). The quality of mushroom protein is high thus making them a great dietary complement for cereal dependent diets that are common in developing countries. Estimations of specific amino acids in oyster mushroom may vary amongst studies depending on the exact strain, substrate and growing conditions, but it is generally agreed that the protein and amino acid value of mushrooms is superior to that of most vegetables (Mattila et al., 2002; Mandeel et al., 2005). While oyster mushrooms are a good source of the essential amino acids, a 100 gram portion of fresh mushroom will not meet the adult daily amino acid requirements (Table 1).

Table 1. Composition of some amino acids in oyster mushroom and some selected vegetables.

Amino acid	Recommended daily requirements[a]		Oyster mushroom[b]	Potato[b]	Carrot[b]	Caulifower[b]
	mg/kg	mg/70kg	----------mg/100g (fresh weigh basis)----------			
Isoleucine	20	1400	82	77	29	88
Leucine	39	2730	139	110	38	130
Lysine	30	2100	126	120	35	120
Methionine	10.4	728	35	29	9	31
Cysteine	4.1	287	28	17	1	15
Phenylalanine	25[c]	1750	111	84	26	84
Tyrosine	25[c]	1750	219	40	14	52
Threonine	15	1050	106	71	26	84
Valine	26	1820	112	120	43	140
Histidine	10	700	65	-	-	-
Tryptophan	4	280	1.37[d]	-	-	-

[a]Joint FAO & WHO (2007). [b]Mattila et al. (2002). [c]25 is the daily recommended requirement for either phenylalanine or tyrosine or the total of both combined. [d]Manzi et al. (1999).

Changes in the protein content of stored mushrooms may occur. In fresh mushroom, the tissue is living and hence there is continued enzymatic activity thus a reduction in the protein content over time would be expected. Preservation strategies such as drying, freezing and some chemical treatments that significantly reduce cellular activity processes would be expected to better maintain protein quantity. Vetter (2003) found no significant differences in the protein content of fresh and conserved mushrooms. Contrary to that, Barros et al. (2007) found a decrease in the crude protein content of dried and cooked mushrooms when compared to frozen ones.

2.3.2. Mineral composition

Mushrooms contribute to the mineral constituent of diet. There are differences between mushroom species as well as within species as affected by genetics and the environment (Kurzman, 1997). Mushroom ash content is estimated to be between 5-12% based on dry matter (Kalac, 2009). Mushroom with the least solid matter was observed to have higher ash content.

There can be post-harvest changes in the mineral content of mushrooms depending on handling. Vetter (2003) reported a decrease in the mineral content of dried stored button mushroom. Coskuner and Ozdemir, (2000) reported a decrease in Fe and Cu in button mushrooms that had been blanched in EDTA before drying. Potassium is the most abundant of minerals contained in mushrooms. The mineral composition of oyster mushrooms as summarized by Mattila et al. (2001) is shown in Table 2.

Table 2. Mineral composition of *Pleurotus ostreatus* mushroom.

Mineral	Fresh weight	Dry weight
Ca, g	0.001	0.01
K, g	2.98	47.3
Mg, g	0.16	2.0
P, g	1.11	13.9
Na, g	0.01	0.13
Cu, mg	0.67	8.4
Fe, mg	4.3	54
Mn, mg	0.89	11
Zn, mg	6.6	83
Se, mg	12	83
Pb, µg	1.6	20
Cd, µg	30	380

Source: Mattila et al. (2001).

2.3.3. Carbohydrates, fiber, and fat

Mushrooms contain carbohydrates but contain no starch (FAO, 2007). On a dry weigh basis, carbohydrates make up 40– 81% in oyster mushroom species thus making them the most abundant component (Bano and Rajarathnam, 1988). Mannitol and trehalose are the dominant carbohydrates found in oyster mushrooms. Mushroom is a good source of dietary fiber with amounts varying depending on the species. Oyster mushroom is reported to contain 7.5-8.7 g/100g per dry weight basis crude fiber (Crisan and Sands, 1978). Mushrooms are low in fat, with a higher percentage (72 to 85%) of the fat being polyunsaturated fatty acids; thus, making them healthy (Mshandete and Cuff, 2007).

2.3.4. Vitamins

Vitamin D is important for the absorption of calcium and bone mineralization (Jasinghe and Parera, 2005) and has been linked to reduced risk of some diseases like diabetes, osteoporosis and heart disorders (Calvo et al., 2006). Vitamin D can become deficient in cold climates, dark skinned individuals, the elderly and those who do not consume meat products. Mushrooms are one of the few fresh foods that naturally contains vitamin D (Jasinghe and Parera, 2005). Fresh mushrooms have very little vitamin D, with higher amounts in the wild mushrooms when compared to cultivated ones (Mattila et al., 2001). The same authors reported that oyster mushroom contained 0.3 µg/100g d.w. of vitamin D. However, ergosterol contained in mushrooms is converted to vitamin D when exposed to light (Jasinghe and Parera, 2005). In comparing several edible mushrooms (i.e. shiitake, enoki, button, oyster and abalone), Jasinghe and Parera (2005) found that although button mushroom had the highest amount of ergosterol, after exposure to UVA irradiation, oyster mushroom had the highest conversion efficiency and in turn had the highest vitamin D_2 content (45.1 ± 3.07 µg/g dw).

Mushrooms contain vitamin B in varying quantities amongst different species. Furlani and Godoy (2008) reported that button mushroom to be superior in vitamin B content; however, oyster and shiitake mushrooms still contained vitamin B that is similar to that found in other vegetables. Mattila et al. (2000) found that oyster mushroom contained moderately high amounts of vitamin B_3 (65mg/100g d.w.), vitamin B_2 (2.5 mg/100 g) and folates (640 µg/100 g dw) with very little quantities of vitamin B_{12} (0.6 µg/100 g dw).

While mushrooms are reported to contain vitamin A and C, these vitamins have been found in very small quantities to none in oyster mushroom (Barros et al., 2007). Jayakumar et al. (2009) reported oyster mushroom to contain 30.3 ± 0.08 vitamin E. Mattila et al. (2000) found

20 mg/100 g (dw) of vitamin C in oyster mushroom. The amounts of antioxidant vitamins are reported to be lower in conserved mushrooms when compared to fresh ones (Furlani and Godoy, 2008; Selvi et al., 2007).

2.3.5. Antioxidants

Among the health benefits of mushrooms are their antioxidant content which help in preventing oxidative stress. Oxidative damage in the body is associated with carcinogenesis and degenerative diseases related to aging (Fu and Shieh, 2002). Oyster mushrooms have been shown to contain phenolic anti-oxidants (Fu and Shieh, 2002) reduced glutathione, ergothioneine (Dubost et al., 2007) and low levels of vitamins A, C, and E (Selvi et al., 2007). Several in vitro experiments have shown oyster mushroom extracts to possess antioxidant and free radical scavenging properties (Fu and Shieh, 2002; Selvi et al., 2007; Barros et al., 2007). Extracts from *Pleurotus ostreatus* were shown to lower induced carbon tetrachloride oxidative activity (Jaykumar et al., 2006) and alleviate damage caused by carbon tetrachloride in the kidneys, heart and brain of Wister rats (Jayakumar et al., 2008). This shows that oyster mushroom can help in the prevention or management of diseases associated with oxidative damage.

2.3.5.1. Phenolic compounds

Phenols are chemical compounds that have a hydroxyl group (-OH) bonded directly to an aromatic hydrocarbon. Total phenols are the most abundant naturally occurring antioxidants in mushrooms (Yang et al., 2002). There is variation (0.39-15.7 mg/g) in the amounts found in oyster mushrooms as reported by different workers. While some workers report reasonable amounts that can benefit consumers (Reis et al., 2012; Dubost et al., 2007; Yang et al., 2002; Fu and Shieh, 2002), some report to have found none to very little (Fu and Shieh, 2002; Mattila et al, 2001) phenolic compounds in oyster mushroom. These variations could be due to several

factors. These include differences in species, strain, substrate, cultivation and fruiting conditions, the developmental stage, and the age of the fresh mushroom sample (Mattila et al., 2001).

Antioxidant capacity of mushroom is highly correlated with amount of phenolic compounds which would suggest that phenolic compounds contribute the most to mushroom antioxidant activity (Guo et al., 2012). However, the individual phenolic compounds may have different antioxidant capacities. The quantities of each phenolic compound found in oyster mushroom varies (Palacios et al., 2011; Reis et al, 2012) and that may also affect the extent to which each compound contributes to the mushroom antioxidant capacity. Some phenolic compounds that have been identified in oyster mushroom include ferulic acid, homogentestic acid, myricetin, protocatechuic acid, p-hydroxybenzoic acid, p-coumaric acid, gallic acid and cinnamic acid (Reis et al., 2012; Palacios et al., 2011). All, except cinnamic acid, were found to have varying degrees of radical scavenging activity with gallic acid having the most activity (Cai et al., 2006).

Flavonoids are a group of naturally occurring phenolic compounds that possess antioxidant properties (Jayakumar et al., 2009). The basic flavonoid structure is composed of two aromatic rings that are connected by a dihydropyrone ring to form a flavonone, or a pyrone ring to form a flavone (Gattuso et al., 2007). The flavonoid structure allows for antioxidant activity through several mechanisms which include scavenging for reactive oxygen species, triggering antioxidant enzymes, metal chelation, α-tocopheryl radical reduction, and oxidase inhibition. Oyster mushroom (*Pleurotus ostreatus*) was found to possess rutin and chrysin (31.2 ± 0.42 and 40.0 ± 0.63 g/100g respectively). Rutin has been shown to possess some iron chelating (Mladěnka et al., 2011) and radical scavenging properties (Afanas' et al., 1989). Chrysin was also reported to chelate iron (Mladěnka et al., 2011). Aside from the antioxidant properties, chrysin

and rutin have also been shown to have some medicinal properties. Chrysin has been reported to inhibit allergic inflammation (Bae et al., 2011) and to possess some anti-cancer properties (Fu et al., 2007). Rutin has also been shown to possess some anti-cancer (Webster et al., 1996) and anti-inflammatory (Lee et al., 2012; Han, 2009) properties in studies done in vivo and *in vitro*.

2.3.5.2. Ergothioneine

Ergothioneine (2-mercaptohistidine trimethylbetaine) is an antioxidant that was discovered in rye ergot, hence its name (Tarnet, 1909). It is colorless, odorless and soluble in aqueous solution and has a relative molecular mass of 229.30g. In its natural form, ergothioneine has the L-configuration around the α carbon with optical rotation of [α]D+116° (Newton et al., 1927). Ergothioneine is known to be formed in some *Actinomycetale* bacteria, cyanobacteria and non-yeast forming fungi (Cheah and Halliwell, 2012). Even though there is no evidence of ergothioneine synthesis in higher animals and plants, it has been found in most of their cells and tissues (Melville, 1959). Human beings have relatively higher concentrations of ergothioneine in specific places such as the erythrocytes, bone marrow, liver, kidneys, seminal fluid, and the lens and cornea of eyes (Melville et al., 1954; Shires et al., 1997; Salt, 1931; Leone and Mann, 1951). In humans, uptake is through diet and since mushrooms synthesize ergothioneine they are a relatively rich source (Ey et al., 2007). Dubost et al., (2007) found the ergothioneine content in white button, crimini, portabella, maitake, shiitake and oyster mushrooms to range between 0.21-2.29 mg/g dw, with oyster mushrooms having the highest quantity. This makes oyster mushroom a good dietary source of ergothioneine.

Even though ergothioneine is found widely distributed in human tissues, its deficiency is not known to cause any symptoms and therefore it is not considered an essential dietary component (Cheah and Halliwell, 2012). However, ergothioneine has been shown to be an

antioxidant. Compared to other antioxidants such as trolox, uric acid and glutathione, ergothioneine was shown to be a more powerful scavenger of hydroxyl radicals, hypochlorous acid and peroxynitrite in studies done in vitro (Franzoni et al., 2006). Dubost et al. (2007) found ergothioneine to have relatively high hydroxyl radical scavenging capacity (HORAC) and peroxynitrite radical averting capacity (NORAC), (231 μmol caffeic acid/g and 407 μmol trolox equivalents/g respectively). High accumulation of ergothioneine has been found associated with organs, cells and secretions that are exposed to high levels of oxidative stress and inflammation (Paul and Snyder, 2010). Silencing ergothioneine transporter protein OCTN1 led to increased mitochondrial DNA damage, protein oxidation and lipid peroxidation (Paul and Snyder, 2010). This would suggest that ergothioneine plays a role in the protection against oxidative damage. However, even though increased levels of ergothioneine and OCTN1 mRNA have been observed in patients with inflammation diseases, its role is debated. While Kato et al. (2010) reported that ergothioneine may have anti-inflammatory properties in Crohns disease patients, other workers (Taubert et al., 2005; Taubert et al., 2009) suggest that ergothioneine may actually stimulate inflammation as a result of its anti-apoptic characteristic.

The antioxidant activity of mushroom may be altered by different processes that occur during preservation and cooking. Selvi et al. (2007) found that both fresh and dried oyster mushrooms contained appreciable amounts of reduced glutathione, vitamins A, C, and E were lower quantities in dried compared to fresh oyster mushrooms were observed. Barros et al. (2007) found more phenol and flavonoid concentrations and antioxidant activity in dried mushrooms when compared to cooked and fresh wild edible mushrooms. While low heating temperatures (i.e. drying) may increase extractability of bound phenolic compounds, high

heating temperatures (i.e. cooking) may destroy phenolic structures. This may reduce the antioxidant activity of the mushroom.

2.4. Mushroom Sensory Quality

The aroma, appearance, flavor and texture of mushroom contribute to its overall sensory quality and hence its consumer acceptability and market value. Fresh mushrooms are usually preferable. However, the fast deterioration rate necessitates preservation methods that help to increase mushroom shelf life. During the preservation process, some quality traits maybe compromised and hence the need for methods that minimize this loss and maximize quality.

Some of the mushroom attributes that contribute to its sensory quality may be evaluated using various instrumental methods as well as through sensory methods, (Jaworska and Bernas, 2010). For example, some known flavor components have been quantified and correlated to mushroom flavor (Cho et al., 2007), while a Kramer shears have been used to evaluate textural properties (Jaworska and Bernas, 2010), and mushroom color has been previously evaluated with the help of a spectrocolorimeter (Czapski and Szudyga, 2000). The strength of correlations between measurements with the use of instruments and the related attribute is variable (Jaworska and Bernas, 2010; Cho et al., 2006). While instrumental evaluation methods have the advantages of requiring fewer people, less time and being easily repeatable, there is still a need to relate measurements to the actual perceptions from human senses. Since several attributes constitute sensory quality, it is not possible to measure all of them with one instrument. Sensory analysis that makes use of human subjects as the instrument of measurement has the advantage of applying actual human senses with the added advantage of evaluating several attributes at the same time.

Sensory evaluation is commonly done by either a descriptive or consumer panel. A descriptive panel is usually made of evaluators who have received some level of training in sensory analysis while consumer panelists do not require previous training (Murray et al., 2001). With either method, there is need for careful preparation and execution of the sensory analysis followed by appropriate data analysis and interpretation.

Preservation methods affect the texture of mushroom, (Jaworska and Bernas, 2010). Several textural attributes that help characterize mushroom texture can be assessed and these may include the extent to which samples are fibrous, slimy, rubbery or hard. Kotwaliwale et al. (2007), investigated the effect of blanching followed by hot air drying at temperatures ranging from 50-70^{o}C. Blanching oyster mushrooms prior to drying resulted in increased hardness with a decrease in cohesiveness and springiness. Hardness was also found to increase with increased drying temperature and this was attributed to the quicker water loss associated with higher temperatures. Czapski and Szudyga (2000) found that blanching button mushrooms before freezing them resulted in increased toughness. This has been attributed to changes in the structure, volume and contents of the mushroom cells during drying (Zivanovic and Buescher, 2004).

Appearance is an essential quality determinant and mushroom color is an important factor since mushrooms are prone to browning. Browning can be the result of several reactions, which include enzymatic reaction of phenols, Maillard browning, ascorbic acid oxidation, caramelization and lipid oxidation (Pizzocaro, 1993). The reaction of polyphenol oxidase is a major factor in the post-harvest browning of both fresh and preserved mushrooms (Rodrı´guez-Lo´pez et al., 1999), which results in changes in appearance and flavor, thus a reduction in market value (Iyengar and McEvily, 1992). Postharvest preservation methods such as blanching

and the use of chemical pretreatments help counter these unfavorable reactions thus promoting better quality. Kotwaliwale et al. (2007) and Gothandapani et al. (1997) found that blanching helped preserve mushroom color. Chemical pretreatments such as citric acid, potassium metabisulfite, ethylenediaminetetraacetic acid (EDTA) have been found to help preserve mushroom color (Coskuner and Ozdemir, 2000; Gothandapani et al., 1997; Rai and Arumuganathan, 2008).

Volatile and non-volatile components contribute towards mushroom flavor (Maga, 1981). These flavor components will change as a result of post-harvest physiological activity, handling, preservation and storage, thus mushroom flavor may be altered. Apart from changes in the intrinsic flavor components, preservation methods such as treatment with chemical preservatives to optimize other mushroom quality attributes may introduce some new flavors which may be undesirable (Iyengar and McEvily, 1992).

2.5. Mushroom Preservation

2.5.1. Dehydration

Fresh mushrooms are highly perishable because they contain about 87 to 95 % water (Arora et al., 2003) thus, are highly perishable. Efficient preservation methods may extend shelf life and diversify the product for consumers. Preservation may also be useful if mushrooms are to be used as an ingredient for the production of other foods like dehydrated instant meals. Dehydration of mushroom is the most common method of mushroom preservation (Arora et al., 2003). Freeze drying of food has been shown to achieve extended shelf life while also maintaining product quality compared to other drying methods. However, freeze drying is a relatively more expensive method of drying and is usually used for high value products (Ratti, 2001). Conventional methods of drying food include solar, oven and air drying. Solar drying,

although characterized by several challenges, remains the oldest and most inexpensive dehydration method. Thermal, physical and chemical treatments applied in drying processes may alter mushroom nutritional and sensory quality.

2.5.2. Pretreatments

Quality degradation in the form of discoloration, development of off-flavors and textural changes cause concern in the preservation of mushroom. Pretreatments are usually applied to prevent such quality losses as well as to reduce microbial infestation. Examples of pretreatments include blanching, smoking, salting and acid pretreatments.

2.5.2.1. Blanching

Blanching is usually done by dipping vegetables in hot water briefly and then taking them out and possibly exposing to cold water to cease the cooking process. Hot water blanching is a common pretreatment which has been shown to improve appearance and rehydration quality of dried mushroom (Gothandapani et al., 1997). The brief exposure to heat inactivates enzyme activity; thus, preventing further breakdown and loss of nutrients as well as discoloration and off flavor development. Blanching prevents vitamin C oxidation by ascorbic acid oxidase and hence reduces ascorbic acid loss from fruits and vegetables (Lee and Kader, 2000). However, blanching by dipping in water, has been shown to result in a loss of some of the water soluble nutrients and hence it reduces the nutritional quality of mushroom (Gothandapani et al., 1997). Steam blanching may possibly reduce the nutrient leaching experienced with hot water blanching.

2.5.2.2. Chemical pretreatments

Chemical pretreatments such as citric acid and potassium metabisulfite can be applied before dehydration to enhance quality (Coskuner and Ozdemir, 2000). One way by which this is achieved is by preventing enzymatic browning. Some of the mechanisms by which chemical

pretreatments help reduce enzymatic browning include enzyme inhibition, chelation at enzyme active site, complexing polyphenol oxidase substrates and altering pH to below the optimum level (Iyengar and McEvily, 1992). Chemical pretreatments may also help to reduce microbial infestation, thereby making dried mushroom safer. This can be achieved by altering the mushroom surface conditions such as pH, thus, making it inhabitable for microorganisms.

While chemical pretreatments may help preserve quality, they negatively affect sensory characteristics and possible nutrient leaching. Gothandapani et al. (1997) found that both blanching and potassium metabisulfite pretreatments resulted in a decrease in the protein and carbohydrate content of dried mushroom when compared to untreated mushrooms. However, the treated mushrooms had better appearance quality. Coskuner and ozdemir (2000) found that EDTA lowered the Fe ad Cu content while the Fe and Cu content in citric acid blanched mushroom was not different from the un-blanched mushroom. Rai and Arumuganathan (2008) reported that use of potassium metabisulfite and sodium benzoate for 15 minutes at 0.5% before drying did not reduce nutritional quality when compared to the untreated control. The effects of the different pretreatments may vary based on the chemical used as well as the period of time the mushroom is dipped in the chemical.

Using chemical preservatives may result in a compromise in flavor. Iyengar and McEvily (1992) reported that while acid treatments may help preserve quality, they may negatively influence taste. Another factor to be considered with the use of chemical pretreatments is that consumers are concerned about the use of additives such as chemical preservatives and the possible effects on their health (Shim et al., 2014). The use of more natural preservatives as opposed to synthetic ones may thus be more preferable.

2.6. References

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CHAPTER 3. DRYING AND PRETREATMENTS AFFECT NUTRITIONAL AND ANTIOXIDANT PROPERTIES OF OYSTER MUSHROOM

3.1. Abstract

The effect of two drying treatments (solar and oven), three blanching treatments (no blanching, water and steam), and four chemical treatments (no chemical, lemon juice, vinegar and potassium bisulfite) on oyster mushroom quality was studied. Total phenolics, total flavonoids, ergothioneine, oxygen radical absorbance capacity, moisture, mineral content, protein and visible mold infestation were evaluated. Lower ergothioneine and total phenolic compounds were observed in blanched mushrooms when compared to the un-blanched ones. Total flavonoids were highest in the water blanched samples and least in the un-blanched ones. Among the chemical pretreatments, higher total phenolic compounds were observed in vinegar and potassium bisulfite treated samples. Blanching resulted in lower K, Mg, Na, S and P content compared to the control. Mineral nutrients varied with chemical pre-treatments. Blanching followed by either lemon juice or no chemical treatment resulted in high mold infestation. Among the un-blanched samples, those treated with vinegar had the least mold infestation. Drying method, blanching, and chemical pretreatments affect oyster mushroom quality as demonstrated in this study.

3.2. Introduction

Oyster mushrooms are a highly nutritious food that contains protein, carbohydrates, vitamins, mineral nutrients, fiber, and antioxidants. About 40-81% (dry weight basis) of oyster mushroom is made up of carbohydrates (Bano and Rajarathnam, 1988). Oyster mushrooms contain high amounts of protein (30-40%, dry weight basis) (Mandeel et al., 2005), which is higher than most vegetable sources. They are also a good source of dietary fiber (7.5-8.7 %, dry

weight basis) (Crisan and Sands, 1987). While oyster mushrooms are reported to contain very little to no vitamin A and C (Barros et al., 2007); they do contain appreciable amounts of vitamin B (Mattila et al., 2000). Mushrooms are the only fresh food that contains vitamin D and oyster mushrooms have been reported to contain (0.3 µg/100 g dry weight basis). While this amount of vitamin D seems low, oyster mushrooms also contain ergosterol which can be converted to vitamin D with exposure to light (Jasinghe and Parera, 2005).

Oyster mushrooms are valued for their antioxidant content. Phenolic compounds constitute the highest amount of mushroom antioxidants (Fu and Shieh, 2002). Oyster mushrooms also contain reduced glutathione, ergothioneine, and low amounts of the vitamin antioxidants (Dubost et al., 2007; Selvi et al., 2013). Their extract has been shown to possess antioxidant activity in studies done in vitro (Fu and Shieh, 2002; Selvi et al., 2013; Barros et al., 2007) and in vivo (Jayakumar et al., 2006 and 2008).

One major challenge associated with oyster mushrooms is that they spoil very quickly. Upon harvest, deterioration in composition as well as sensory quality occurs rapidly and hence a need for preservation methods that help extend shelf life while optimizing quality. The objective of this study was to evaluate the effect of preservation methods on the nutritional and antioxidant properties of oyster mushrooms.

3.3. Objectives

1. To determine the effect of drying and pretreatments on the oyster mushroom nutrition,
2. To determine the effect of drying and pretreatments on oyster mushroom antioxidant content and activity.

3.4. Materials and Methods

3.4.1. Experimental design

An experiment was conducted to determine the effect of pretreatments and drying on the quality of oyster mushroom. The specific treatments were as follows: two drying treatments (solar, and oven), three blanching treatments (no blanching, steam, water), and four chemical pretreatments (no chemical pretreatment, potassium bisulfite, vinegar, and lemon juice). The drying experiment was laid out in split block with the drying methods (solar and oven) as the two main blocks. Within each block, there was a factorial arrangement of the 3 blanching and 4 chemical treatments. There were three replications with randomization done within each rep.

3.4.2. Mushroom sample preparation

3.4.2.1. Chemicals and mushroom

Fresh oyster mushroom for this study was donated by Super Value, Fargo, ND. Potassium bisulfite was obtained from VWR (Radnor, PA). Distilled white vinegar and lemon juice were obtained from Hornbacher's grocery store, Fargo, N.D.

3.4.2.2. Chemical pretreatment

Once obtained, the mushroom was trimmed and weighed into 100 g sample units. Each sample unit was blanched for 3 minutes using steam or boiling water. This was followed by soaking in 500 ml of 0.5% chemical pretreatment solution for 10 minutes. Samples were then drained and dried in either a solar drier or in the oven.

3.4.2.3. Drying

Oven drying was done at a temperature of 43 ^{o}C. Hobo U12 data loggers were used to monitor the temperature and humidity in the oven during drying. The drying temperature, relative humidity and light intensity are summarized in appendix tables A1- A14. The mushroom

was dried on three shelves with each shelve carrying a single replication. Randomization was done within the replications. There was periodic rotation of the shelves during the drying period. Three solar driers were constructed and used for this study. Two of them were similar in design and the third one was different. Solar driers were constructed in Fargo, North Dakota and all the materials needed were purchased from local hardware stores in 2011. The first solar drier (Appendix Figure A15.) was constructed based on a design by Fodor (2005). The second and third solar driers (Appendix Figure A16.) were constructed based on a design described by Akoy et al. (2006) with some modifications. The driers were mainly built out of wood with plexi glass screens.

Solar drying was done at ambient temperatures. Each of the three driers was used to dry a single replicate at a time. Data loggers were used to monitor the temperature and humidity inside the solar driers during the drying period. Solar driers were taken outside and set under direct sunlight at sunrise and taken indoors at sundown. The driers were moved as needed throughout the day to make sure they remained facing the sun without any shadows falling on them. Overnight, the driers were indoors in an air conditioned room.

Dried mushroom samples were ground using a coffee grinder. The powder was sieved through a size 16 mesh screen then packed in sterile bags then placed in the freezer (-18 ^{o}C) until analysis was completed.

3.4.3. Moisture determination

Oven drying method was used for moisture determination (AOAC, 1996). An initial weight of 0.5 g of the ground mushroom powder was weighed and dried in an oven set at 105 ^{o}C for 5 hours. Samples were reweighed and moisture percentage was calculated as follows; (initial sample weight-dried sample weight) / initial sample weight) x 100.

3.4.4. Determination of percent mold infested samples

After drying, each sample unit was inspected for any visible mold. A score of 1 was given for sample units that had any visible mold whereas a score of 0 was given to any sample units that had no visible mold. The average percentage of mold infested samples per each treatment was then determined [(number of samples with visible mold/ number of samples without any visible mold) × 100].

3.4.5. Mineral analysis

Mushroom samples were submitted to the North Dakota State University Biological Science Lab for mineral analysis. To 0.25 mg of ground mushroom powder, 5 ml of HNO_3 was added and this was allowed to stand for about 2 hours. Five ml of deionized water was added and this was followed by microwave digestion at 180 ^oC in a CEM Mars Xpress microwave digester. Digested samples were then analyzed for mineral content (Ca, Cu, Fe, K, Mg, Mn, Na, P, S and Zn) using a SpectroGenesis ICP-OES.

3.4.6. Crude protein

Crude protein was estimated from nitrogen content using a conversion factor of 4.97 which is specific for oyster mushroom (Mattila et al., 2002). For the nitrogen determination, 30 mg of ground oyster mushroom was weighed onto foil and rolled into little foil pellets. This was followed by analysis on a CHNOS elemental analyzer. The analysis included combustion at 1,150 ^oC followed by mineral nutrient determination.

3.4.7. Total phenolic and flavonoid content

3.4.7.1. Chemicals

Methanol (HPLC grade), Folin and Ciocalteu's phenol reagent, Gallic acid, $NaNO_2$, $AlCl_3$, NaOH and (+)-Catechin were purchased from VWR (Radnor, PA, USA).

3.4.7.2. Extraction

Total phenolic and flavonoid content was analyzed based the method described by Barros et al. (2007) with some minor adjustments. 50 ml methanol was added to 1g of ground oyster mushroom. This was placed on a shaker at 150 rpm for 24 hours then centrifuged at 4,000 rpm for 20 minutes followed by decanting of the liquid extract. This was repeated twice and the liquid extract from each sample was combined then evaporated to dryness under nitrogen flow at 40 ^{o}C. The residue was then re-dissolved in methanol at a concentration of 50 mg/ml and stored at 4 ^{o}C.

3.4.7.3. Phenolic content determination

One ml of the methanolic extract was mixed with 1 mL of Folin and Ciocalteu's phenol reagent. To this, 1 ml of saturated sodium carbonate solution was added. The mixture was left to stand for 3 minutes then topped up to 10 ml with distilled water. The solution was left to stand in the dark for 90 min then readings were taken on a Varian Cary 50 Bio UV spectrophotometer at an absorbance of 725 nm. Gallic acid was used for the standard curve and results were expressed as mg/g gallic acid equivalents (GAE). The standard curve ranged from 0 mg/g to 5 mg/g.

3.4.7.4. Flavonoid content determination

Two hundred and fifty µl of the mushroom methanol extract was mixed with 1.25 ml distilled water and 75 µl of a 5 % $NaNO_2$ solution. This mixture was left to stand for 5 minutes. One hundred and fifty microliters 10% $AlCl_3 \cdot H_2O$ solution was added and mixture was left to stand for 6 minutes. Then 500 µl of 1 M NaOH and 275 µl of distilled water were added and after thorough mixing, the pink color intensity was measured on a Varian Cary 50 Bio UV spectrophotometer at 510 nm. (+)-catechin was used to calculate the standard curve and results were express as mg/g (+)-catechin equivalents.

3.4.8. Ergothioneine determination

3.4.8.1. Chemicals

Ergothioneine standard, ethanol (HPLC grade), acetonitrile (HPLC grade), acetic acid, diethiothreitol (DTT), betaine, 2-mercapto-l-methyl imidazole (MMI), sodium dodecylsulfate (SDS), sodium phosphate, and triethylamine, were purchased from VWR (Radnor, PA, USA). Deionized nanopure water was obtained from the lab.

3.4.8.2. Procedure

Ergothioneine determination was based on a procedure by Dubost et al. (2007). To 1 g of the mushroom powder, 20 ml of cold ethanolic extraction medium (10 mM DTT, 100 µM betaine, and 100 µM MMI in 70 % ethanol) was added and mixed well. One percent ethanolic solution (4 ml) of SDS was added and this was followed by centrifuging for 20 minutes at 4,000 rpm. The supernatant solution was removed and vortexed to allow uniform mixing. One milliliter was extracted and evaporated to dryness under a stream of ultrapure nitrogen gas. The resulting residue was then re-suspended in 0.5 ml of water (adjusted to a pH of 7.3). The solution was centrifuged for one minute at 1,000 rpm then filtered through a 0.45 µm filter prior to injection into the HPLC.

Analysis was carried out on an Alliance Waters HPLC 2795 unit (Waters Corp., Milford, CT, USA). Separation was carried out on one Kinetex 5 µm XB-C18 column (Phenomenex, Torrance, CA, USA) that was 250 x 4.6 mm. The degassed (ultrapure nitrogen) isocratic mobile phase was 50 mM sodium phosphate in water with 3% acetonitrile and 0.1% triethylamine adjusted to a pH of 7.3 with a flow rate of 1 mL per minute. The injection volume was 10 µl and the columns temperature was ambient. An UV-VIS detector (Waters Corp., Milford, CT, USA) at a wavelength of 254 nm was used to measure absorbance.

3.4.9. Oxygen radical absorbance capacity ($ORAC_{FL}$)

3.4.9.1. Chemicals

Trolox (6-Hydroxy-2,5,7,8-tetramethylchroman- 2-carboxylic acid) and Fluorescein (FL) (Na salt) were obtained from Sigma Aldrich (Milwaukee, WI). The 2,2'-azobis (2-amidino-propane) dihydrochloride (AAPH) was purchased from Wako Chemicals USA (Richmond, VA). Randomly methylated *â*-Cyclodextrin (RMCD) (Trappsol) (pharmacy grade) was obtained from Cyclodextrin Technologies Development Inc (High Springs, FL).

3.4.9.2. Plate reader specifications

The Germini^{TM} EM Fluorescence Microplate reader was used for $ORAC_{FL}$ analysis. Fluorescence filters with an excitation wavelength of 485 nm and an emission wavelength of 520 nm were used. Ninety six well FLUOTRAC black microplates (VWR, Radnor, PA, USA) were used for the analysis. A maximum of 48 wells were used at a time so that time taken while pipetting solutions would not affect reaction time.

3.4.9.3. Extraction of mushroom samples

The $ORAC_{FL}$ assay was done following the method described by Prior et al. (2003). One gram of oyster mushroom powder from each sample was extracted twice using 10 ml of hexane each time. Centrifugation at 3,500 rpm for 15 minutes was done and the two hexane layers from each sample were removed and combined. Residual hexane was evaporated from the remaining residue and this was followed by further extraction with 10 ml of acetone/water/acetic acid, (70/29.5/0.5, v/v/v). After the solvent was added, the tube was vortexed for 30 sec, followed by sonication at 37 °C for 5 minutes with the tube being inverted once during the sonication step to suspend the samples. The tube was left to stand at room temperature for 10 min with occasional

shaking. This was followed by centrifugation at 3,500 rpm for 15 minutes. The supernatant was removed and diluted to a total volume of 25 ml.

3.4.9.4. Lipophilic ($ORAC_{FL}$) assay

For the lipophilic antioxidant assay, the combined hexane layers were dried under nitrogen flow. The remaining residue was dissolved in 250 µl of acetone and then diluted with 750 µl of a 7% RMCD solution (50% acetone/50% water, v/v). To a 96 well microplate, 20 µl of the mushroom extract solution, 200 µl of fluorescein solution, and 75 µl of AAPH (17.2 mg/ml) were added. Readings were immediately started. Only 48 of the 96 well were used. The fluorescence plate reader's incubator was set at 37 °C. Readings were taken every 2 minutes for a period of 40 minutes. Before each reading, the microplate contents were automatically mixed for 8 seconds. Trolox was used for the standard curve and results were expressed as µmol trolox equivalents (TE)/g). The 7% RMCD solution was used as the blank and for dissolving the trolox standards for the lipophilic assay.

3.4.9.5. Hydrophilic ($ORAC_{FL}$) assay

For the hydrophilic assay, the diluted acetone/water/acetic acid extract was used. To each microplate well, 20µL of the extract, 200 µl of fluorescein solution, and 37.5 µl of AAPH (17.2 mg/ml) were added and readings were started immediately in the same manner as described for the lipophilic assay. Trolox was used for the standard curve and results were expressed as µmol trolox equivalents (TE)/g. The phosphate buffer was used as the blank and for dissolving the trolox standards for the lipophilic assay.

3.4.10. Statistical analysis

Analysis of variance was done using Statistical Analysis System (SAS Inst., 1988) and least significant differences were used to separate means.

3.5. Results

3.5.1. Moisture

There were no significant differences in moisture among the different treatments (Table 3; Appendix Table A1). Average moisture content across all treatments was 10.1%.

Table 3. Moisture content of dried oyster mushroom with different drying, blanching and chemical treatments.

Treatment	Mean±standard error	Significance
	-------%-------	
Solar drying	9.66±0.58	NS[a]
Oven drying	10.64±0.77	NS
No blanching	11.72±0.83	NS
Water blanching	8.96±0.62	NS
Steam blanching	9.76±0.89	NS
No chemical	7.99±0.74	NS
Potassium bisulfite	10.45±1.02	NS
Vinegar	11.15±1.07	NS
Lemon juice	11.00±0.95	NS

[a]NS denotes means are not significantly different at $p \leq 0.05$.

3.5.2. Antioxidants

3.5.2.1. Total phenolic content

Drying method did not significantly ($p<0.05$) affect total phenolic content (Appendix Table A2). There was significant ($p<0.05$) blanching method x chemical pretreatment interaction on the total phenolic compound content (Table 4). Vinegar and potassium bisulfite treated samples that received no blanching contained 8.31±0.53 and 8.4±0.64 mg/g GAE respectively,

which was much higher than all the other treatments. Samples that were water blanched followed by soaking in a chemical pretreatment had less total phenolic content when compared to water blanched samples that received no chemical pretreatment (Table 4). Among the samples that received a chemical pretreatment, the un-blanched samples had more total phenolic content compared to the blanched samples.

Table 4. Total phenolic content[a] of dried oyster mushroom treated with different chemical pretreatments and blanching methods.

	Blanching method		
Chemical	No blanching	Water	Steam
	----------mg/g----------		
No chemical	2.52±0.19 bA	1.34±0.15 aB	2.45±0.35 abA
Potassium bisulfite	8.4±0.64 aA	0.98±0.23 aC	3±0.63 aB
Lemon juice	3.24±0.55 bA	0.99±0.05 aC	2.03±0.32 abB
Vinegar	8.31±0.53 aA	0.81±0.12 aC	1.93±0.50 bB

[a]Mean ± standard error is shown. Separation within columns was done using small caps and separation within rows is done using large caps. Means followed by the same letter are not significantly different each other ($p \leq 0.05$).

There were significant differences ($p<0.05$) in the mushroom total phenolic content among the different chemical pretreatments (Table 5). Total phenolic compounds were significantly higher in mushrooms treated with potassium bisulfite and vinegar (Table 5). Blanching method resulted in a significant difference ($p<0.05$) in total phenolic compounds (Table 6). The highest amount of phenolic compounds was found in the un-blanched samples. This was followed by the steam blanched samples with the least amount being observed in the water blanched mushrooms.

Table 5. Antioxidant composition[a] of dried oyster mushrooms treated with different chemical preservatives.

Chemical treatment	Lipophilic ORAC	Total phenolics
	----------mg/g----------	
No chemical	11.51±0.17 b	2.10±0.17 b
Potassium bisulfite	11.98±0.25 ab	4.13±0.61 a
Lemon juice	11.75±0.2 ab	2.09±0.26 b
Vinegar	12.21±0.24 a	3.68±0.61 a

[a]Mean ± standard error is shown. Means followed by the same letter are not significantly different from each other ($p \leq 0.05$).

Table 6. Antioxidant composition of oyster mushroom treated with different blanching methods.

Blanching method	Total flavonoids	Total phenolic	Ergothioneine
	----------mg/g----------		
No blanching	2.10 ± 0.17 c	5.62 ± 0.47 a	0.27 ± 0.03 a
Water	4.47 ± 0.32 a	1.03 ± 0.08 c	0.08 ± 0.01 c
Steam	3.33 ± 0.22 b	2.35 ± 0.23 b	0.13 ± 0.01 b

[a] Mean ± standard error is shown. Means followed by the same letter are not significantly different from each other ($p \leq 0.05$).

The combination of blanching with soaking in chemical pretreatments presented two opportunities for nutrient leaching and hence the observed lower phenolic content. The presence of vinegar and potassium bisulfite on the surface of the un-blanched mushroom samples resulted in higher total phenolic content. In this study, total phenolic compounds were evaluated using the Folin reagent. This method measures the total reducing capacity of a substance and thus it has potential for interference from any compounds with reducing power other than phenolic compounds. Potassium bisulfite is a reducing agent and hence the higher total phenolic content observed in potassium bisulfite treated samples may have been related to this compound.

Although interference from organic acids has been reported, none has been specifically observed with acetic acid. Lopez et al. (2005) found that common white vinegar contained some polyphenols but no flavonoids class was detected. Therefore, the vinegar treatment could have increased the total phenolic content.

The effect of blanching on the antioxidant content of mushrooms could be due to several aspects which include blanching temperature, duration of heat exposure, leaching, pH, and the presence of oxygen and other phytochemicals (Ioannou et al., 2012). Depending on the individual phenolic compound, blanching may result in an increase or a decrease in quantity. Kaiser et al. (2013) found that when exposed to steam or water for 1 minute, apiin was found to decrease whereas malonylapiin B increased. In this current study, the lower total phenolic compounds in the blanched samples was attributed to leaching. It is possible that blanching may have had effects that made it easier for phenolic compounds to be lost. This may include a release of bound phenolic compounds and possibly disruption of both phenolic compound structure and that of the cell walls with an overall effect of making it easier for the phenolic compounds to be leached out during blanching.

The lower total phenolic content associated with the water blanched samples, suggests that this leaching was worse with water blanching compared to steam blanching. While both blanching methods expose the mushroom to heat and thus the associated effects on mushroom cell and antioxidant structure, water blanching presents an opportunity for the mushroom to be immersed in hot water hence more compounds may move out of the mushroom cell and be lost in the remaining blanching water. Barros et al. (2007) also found that total phenolic compounds in mushrooms decreased with cooking and this was attributed to the negative effects of heat on the antioxidant structure.

3.5.2.2. Total flavonoid content

Drying method had no significant ($p<0.05$) effect on total flavonoid content (Appendix table A3). There was significant ($p<0.05$) blanching method x chemical pretreatment interaction on total flavonoid content (Table 7). The combination of blanching and soaking in the different pretreatments resulted in higher total flavonoid content. All the un-blanched samples, with the exception of the ones treated with potassium bisulfite, had the lowest total flavonoid content. Flavonoid content was significantly ($p<0.05$) higher in the blanched samples compared to the un-blanched ones (Table 6). Water blanching resulted in higher total flavonoid content when compared to steam blanching.

Table 7. Total flavonoid content[a] of dried oyster mushroom treated with different chemical pretreatments and blanching methods.

	Blanching method		
Chemical	No blanching	Water	Steam
	----------mg/g----------		
No chemical	1.16±0.16 Bc	2.87±0.32 Ab	2.04±0.20 Cb
Potassium bisulfite	3.46±0.3 Aa	3.39±0.74 Ab	2.62±0.46 Bb
Lemon juice	1.81±0.27 Cb	5.98±0.41 Aa	4.06±0.22 Ba
Vinegar	1.96±0.15 Cb	5.61±0.56 Aa	4.6±0.30 Ba

[a]Mean ± standard error is shown. Mean separation within columns was done using lower case letters and separation within rows was done with upper case letters. Means followed by the same letter are not significantly different from each other ($p \leq 0.05$).

The higher flavonoid content in the blanched samples could be attributed to the effect of heat on flavonoid availability. Choi et al. (2006) found that when shiitake mushroom received heat treatment at 100 and 121 ^{o}C, for 15 and 30 minutes, the free flavonoids increased while the bound flavonoids decreased with an overall effect of increased total flavonoid content. These

changes were attributed to the disruptive effect of heat on the cell wall. This resulted in a release of previously bound flavonoids.

Given that blanching mushrooms and soaking them in chemical treatments both present opportunities for nutrient leaching; these results would suggest that polyphenols in the flavonoid class were not as prone to leaching. Both blanching and chemical pretreatments have negative effects on polyphenol oxidase activity. Thus, a combination of both treatments would be expected to help preserve polyphenols which could have contributed to the higher total flavonoids. It is also possible that the chemical pretreatments had a direct effect on the observed total flavonoid content. Lemon juice is known to contain flavonoids (Gattuso et al., 2007) and this may have contributed to the total flavonoid content found in lemon juice treated samples.

3.5.2.3. Ergothioneine

There was a significant difference ($P<0.05$) in ergothioneine content among the blanching treatments (Table 6; Appendix table A4). Ergothionenine was highest in the un-blanched samples, followed by the steam blanched samples and least in the water blanched mushrooms. This loss was probably due to leaching. Nguyen et al. (2012) steamed, boiled and microwaved *Flammulina velutipes* mushroom for 2-5 minutes and found that these treatments decreased the amount of ergothioneine with the highest loss being in the boiled mushrooms. In their study, heat degradation was ruled out and the decrease was attributed to leaching.

3.5.2.4. Oxygen radical absorbance capacity

There were no significant differences ($p<0.05$) in the hydrophilic and total ORAC values among the different treatments (Appendix tables A5 and A6 respectively). There were significant differences ($p<0.05$) in the lipophilic ORAC values for mushrooms treated with different chemical pretreatments (Table 5; Appendix Table A7). Vinegar had the highest lipophilic ORAC

value. However, this value was not statistically different from the samples treated with potassium bisulfite and lemon juice.

Across all treatments, the average hydrophilic and lipophilic ORAC values were 59.8 and 11.9 µmol TE/g respectively. The hydrophilic and lipophilic ORAC values for solar and oven dried mushrooms that received no blanching or chemical treatment (Table 8) are higher than the 49.67 and 5.67 µmol TE/g previously reported for hydrophilic and lipophilic ORAC values observed in freeze dried oyster mushroom (Dubost et al., (2007). The observed differences in antioxidant content (ergothioneine, total phenolic content and total flavonoids) did not translate to differences in ORAC values. Dubost et al. (2007) also found that differences in mushroom ergothioneine were not correlated to ORAC values. However, contrary to this current study, they found that total phenolic content was positively correlated to total ORAC values. While total phenolic content may sometimes be positively correlated to ORAC values, this is not always true for all foods (Wu et al., 2004). This is because there maybe differences in the antioxidant capacity of the individual phenolic compounds. Apart from phenolic compounds, there may also be some other antioxidants contributing to antioxidant activity.

Table 8. The ORAC[a] values for solar and oven dried oyster mushroom.

Drying method	Hydrophilic ORAC	Lipophilic ORAC
	----------µmol/g----------	
Oven	63.4±0.93 a	12.3±0.15 a
Solar	56.2±1.07 a	11.4±0.14 a

[a]Mean ± standard error is shown. Means followed by the same letter are not significantly different from each other ($p \leq 0.05$).

3.5.3. Mineral composition

There was significant blanching method x chemical pretreatment interaction on sodium content (Table 9; Appendix Table A8). The highest amount of sodium (263±8.7) was observed in mushroom that had a lemon juice pretreatment with no blanching. Sodium content significantly ($p<0.05$) varied with chemical pretreatment (Table 10).

Table 9. Sodium content[a] of dried oyster mushroom treated with different chemical pretreatments and blanching methods.

Chemical	Blanching method		
	No blanching	Water	Steam
	----------mg/kg----------		
No chemical	107±12.3 bA	79.8±8.2 bB	105±7.8 bA
Potassium bisulfite	101±7.9 bA	55.2±4.3 cB	71.7±5.4 cB
Lemon juice	263±8.7 aA	158.8±5.7 aC	199±12.6 aB
Vinegar	95±5.4 bA	61.3±4.0 cB	77.4±6.5 cAB

[a]Mean ± standard error is shown. Mean separation within columns was done using lower case letters and separation within rows was done with upper case letters. Means followed by the same letter are not significantly different from each other ($p\leq0.05$).

Oyster mushroom sodium content ranged from 39.88-276 mg/kg across all treatments. Given the 2,400 milligrams daily maximum intake (Anonymous, 2008). This amount still low enough for these mushrooms to be considered a low sodium food. Bottled lemon juice is reported to contain some sodium but in very low quantities (3 mg/tablespoon) (Anonymous, 2008). It is possible that sodium from the lemon juice contributed to the sodium content detected in the lemon juice treated samples. The amount of sodium absorbed from the lemon juice by the fresh mushroom tissue during blanching may have been concentrated during drying hence the higher than expected amount of sodium in the lemon juice treated samples.

Table 10. Mineral composition[a] of dried oyster mushrooms treated with different chemical pretreatments.

Chemical	Ca	K	Mg	Mn	Na	S
	----------mg/kg----------					
No chemical	75±4.3b	22503±688b	1034±16a	6.61±0.2a	97±5.8b	1803±53b
KBS[b]	61±3.7c	26134±1208a	896±26b	5.62±0.3c	76±4.6c	6933±351a
Lemon juice	108±4.7a	17324±834c	913± 24b	5.83±0.3bc	207±9.0a	1727±40b
Vinegar	97±6.0a	16595±795c	926±26b	6.2±0.3ab	78±3.8c	1677±71b

[a]Mean ± standard error is shown. Means followed by the same letter are not significantly different from each other ($p \leq 0.05$). [b]KBS means potassium bisulfite.

There was significant blanching method x chemical treatment interaction on sulfur content (Table 11; Appendix Table A9). The highest amount of sulfur was observed in samples treated with potassium bisulfite (Tables 10 and 11). When mushrooms were treated with potassium bisulfite, sulfur was highest in the un-blanched samples. Given that potassium bisulfite contains sulfur, these results were expected.

Table 11. Sulfur content[a] of dried oyster mushroom treated with different chemical pretreatments and blanching methods.

	Blanching method		
Chemical	No blanching	Water	Steam
	----------mg/kg----------		
No chemical	1986±104 bA	1589±78 bB	1833±55 bAB
Potassium bisulfite	9381±370 aA	6053±190 aB	5363±393 aC
Lemon juice	1929±37 bcA	1604±65 bA	1646±62 bA
Vinegar	1630±76 cAB	1506±76 bB	1893±171 bA

[a]Mean ± standard error is shown. Mean separation within columns was done using lower case letters and separation within rows was done with upper case letters. Means followed by the same letter are not significantly different from each other ($p \leq 0.05$).

Sulfites have been shown to be effective mushroom preservatives (Gothandapani et al., 1997; Rai and Arumuganathan 2008). While sulfite preservatives are effective in protecting against browning and microbial infestation, sensitivity to sulfites has been observed, commonly amongst those with asthma (Yang and Purchase, 1985).

There were significant differences in K, Mg, Na, S and P among the different blanching methods (Table 12; Appendix Tables 10, 11, 12, 9 and 13 respectively). There was higher mineral content in the un-blanched samples when compared to the blanched ones. With the exception of S, steam blanching mushrooms resulted in higher mineral content when compared to water blanching.

Table 12. Mineral composition[a] of dried oyster mushrooms treated with different blanching methods.

Blanching method	K	Mg	Na	S	P
	----------mg/kg----------				
No blanching	25962±945 a	102 ±19 a	141.31±11 a	3732±486 a	6893±159 a
Water	15649±647 c	818±18 c	88.794±7 c	268±289 b	5602±124 c
Steam	20306± 91 b	985±19 b	113.27±9 b	2688±249 b	6316±161 b

[a]Mean ± standard error is shown. Means followed by the same letter are not significantly different from each other ($p \leq 0.05$).

The observed loss of mineral nutrients following blanching treatments was be attributed to leaching which was higher with water when compared to steam blanching. The reported effect of preservation treatments on mushroom mineral nutrition has been variable. Coskuner and Ozdemir (2000) found that while blanching in a citric acid solution did not reduce mineral content, blanching with EDTA reduced the amount of Fe and Cu in button mushroom. Vetter (2003) found that K, P and Mg decreased after button mushroom had been washed and dried. In both studies, the decrease in some mineral elements after blanching was attributed to leaching.

Some mineral elements have been shown to increase after cooking or blanching (Manzi et al., 2001) as a result of decreased water content thus a concentration of the mineral nutrients. Depending on the quality of water used for processing, there is also a possibility of some mineral elements moving from the water into the mushroom (Rickman et al., 2007).

There were significant differences ($P<0.05$) in Ca, K, Mg, Mn, Na and S among the mushrooms treated with different chemical pretreatments (Table 10; Appendix Tables 14, 10, 11, 15, 8 and 9). Calcium was highest in samples treated with lemon juice and vinegar and least in those treated with KMS. Vinegar has been shown to improve Ca solubility and hence its availability (Kishi et al., 1999). Lemon juice contains some Ca and this could have added to the amount found in the mushroom. Lemon juice also contains citric acid (Penniston et al., 2008) which has been shown increase Ca availability (Lacour, 1997).

Magnesium and Mn were higher in the samples with no chemical treatments (Table 12). As would be expected, K and S were highest is samples treated with potassium bisulfite. Calcium, K, Mg, Na and S are the mineral found in the most quantities in mushroom (Kalac, 2009). Even though different treatments affected mineral nutrition, the quantities were still found in amounts that would be beneficial in the human diet making oyster mushroom a good source of mineral nutrients. There were no significant differences ($P<0.05$) in Cu and Fe across all treatments (Appendix tables 16 and 17 respectively).

3.5.4. Crude protein

There were no significant differences in the crude protein content among the different treatments (Table 13; Appendix Table 18). The average protein content across all samples was 24% dw. There is wide variation in the amount of crude protein detected in oyster mushroom. Content as high as 30-40% has been previously reported (Mattila et al., 2002). Similar to the

current study, Gothandapani et al., (1997) reported crude protein content of 16.8-26.4% in oyster mushroom. Variation may be due to differences in mushroom strain and growing conditions.

Table 13. Crude protein content of dried oyster mushroom treated with different drying methods, chemical pretreatments and blanching methods.

Treatment	Mean±standard error
	-------%-------
Solar drying	25.3±2.89 a
Oven drying	21.8±0.46 a
No blanching	23.2±0.58 a
Water blanching	21.2±0.49 a
Steam blanching	26.1±4.33 a
No chemical	23.2±0.44 a
Potassium bisulfite	27.5±5.77 a
Vinegar	21.8.±0.55 a
Lemon juice	21.7±0.77 a

Means followed by the same letter are not significantly different from each other ($p \leq 0.05$).

3.5.5. Mold infestation

Some of the treated mushroom samples developed mold during the drying process. Amongst the samples that had mold visual comparison showed variations in the extent to which mushroom pieces were infested (Figure 1(a), (b) and (c)). For this study, visual assessment was used to separate sample units that did not have mold from those that had mold without considering the extent of infestation.

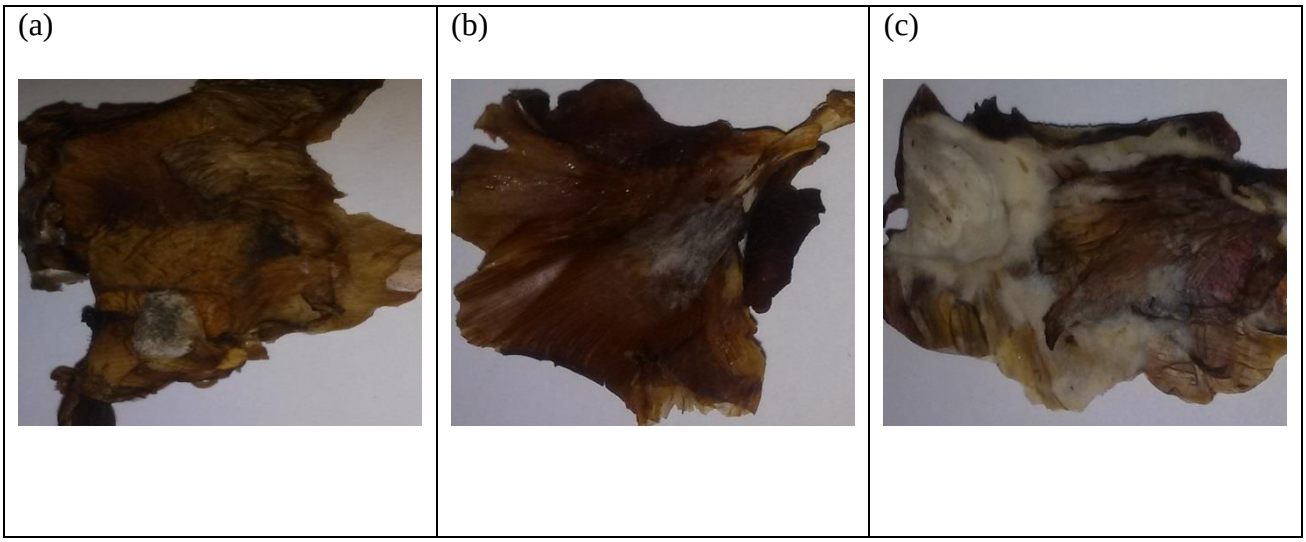

Figure 1. Dried oyster mushroom that was mold infested. Variations in the extent of mold infestation are depicted in (a), (b) and (c).

There was significant ($p<0.05$) blanching method x chemical pretreatment interaction on the mushroom mold infestation (Table 14; Appendix Table 19). Samples that received no chemical pretreatment and those that were treated with lemon juice had relatively high mold infestation despite the blanching treatment. Lemon juice was shown to be ineffective against mold. The least mold infestation was observed on mushroom that had been water blanched followed by a potassium bisulfite pretreatment (Table 14). When blanching was combined with vinegar or potassium bisulfite, mold was most effectively controlled. The un-blanched mushrooms, with the exception of those treated with vinegar, had very high (more than 68%) mold infestation. Water or steam blanching alone without any chemical pretreatment resulted in the highest mold infestation.

There was a significant difference ($p\leq0.05$) in the mold infestation of mushrooms with different chemical pretreatments (Table 15). Treating the mushrooms with vinegar and potassium bisulfite resulted in the least mold infestation, while mushrooms that received no chemical treatment and those that received the lemon juice treatment had high mold infestation.

Table 14. Mold infestation[a] on dried oyster mushroom treated with different chemical pretreatments and blanching methods.

	No blanching	Water	Steam
	----------% ----------		
No chemical	68.5±10.2 aB	91.0±6.3 aA	100±0 aA
Potassium bisulfite	77.3±9.1 aA	0±0 bC	41.0±10.1 bB
Lemon juice	77.3±9.1 aA	72.7±7.5 aA	86.4±7.5 aA
Vinegar	27.3±9.7 bA	13.6±7.5 bA	13.6±7.5 cA

[a]Mean ± standard error is shown. Mean separation within columns was done using lower case letters and separation within rows was done with upper case letters. Means followed by the same letter are not significantly different each other ($p \leq 0.05$).

Table 15. Mold infestation[a] of dried oyster mushroom treated with different chemical treatments.

Chemical treatment	Average mold infestation
	----------% ----------
No chemical	86.4±4.3 a
Potassium bisulfite	39.4±6.1 b
Lemon juice	78.8±5.1 a
Vinegar	18.1±4.8 c

[a]Mean ± standard error is shown. Means followed by the same letter are not significantly different from each other ($p \leq 0.05$).

The combination of blanching and vinegar or potassium bisulfite treatments presented two opportunities for the control of mold and hence the observed lower infestation. The observed lower mold infestation with the combination of blanching and vinegar or potassium bisulfite could have resulted from an initial reduction of the microbial load through blanching and continued suppression of mold populations from the effects of vinegar and potassium on the mushroom surface. During blanching, high temperatures and the reduction in oxygen (Rai and Arumuganathan, 2008) may reduce microbial populations. Gartner et al., (1997) reported a

reduction in mesophilic microbial load of blanched salads. Sulfurous acid salts do possess some antifungal properties. Kolaei et al. (2012) found sulfur containing salts to effectively control post-harvest fungal rots on carrot. Acetic acid has some antimicrobial properties (Sholberg et al., 2000). While several studies have shown the effectiveness of vinegar to possess anti-bacterial properties on food (Medina et al., 2007; Sengum et al., 2004; Jain et al., 2013), there is limited evidence that supports its effectiveness against fungal infestations. However, in this study, vinegar was shown to be the most effective in controlling mold.

Blanching alone may reduce the initial microbial load. It may also expose the fresh mushroom tissue to heat which inactivates physiological processes that cause deterioration. However, it leaves the mushroom tissue more vulnerable to microbial infestation when compared to its fresh state, hence the very high mold infestation observed on mushrooms that were blanched with no chemical pretreatment. The use of chemical pretreatments after blanching discouraged mold infestation.

3.6. Conclusions

There was no difference in the nutritional quality of oven and solar dried oyster mushrooms. Blanching and chemical pretreatments had an effect on mushroom quality. Blanching followed by chemical pretreatments resulted in lower total phenolic compounds but higher total flavonoids content. Pretreatment with potassium bisulfite and vinegar resulted in higher total phenolic content when compared to lemon juice. Blanching oyster mushrooms resulted in lower Mg and K content. Ergothioneine content was lower in blanched samples. No difference in antioxidant capacity was observed among the different treatments. Vinegar and potassium bisulfite had relatively better visible mold control when compared to lemon juice and the control. Drying method had no effect on the mushroom nutritional quality. The chemical and

physical changes that take place during pretreatment and drying did result in differences in oyster mushroom nutritional quality. When selecting blanching methods and chemical pretreatments; there is a need to consider the possible nutritional compromise, thus select methods that will maximize nutritional quality.

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CHAPTER 4. DRYING AND PRETREATMENTS AFFECT THE SENSORY QUALITY OF OYSTER MUSHROOM

4.1. Abstract

Oyster mushrooms are nutritious, flavorful, and are known to have some medicinal properties. Their production requires low capital investment and minimal expertise and thus they can potentially be a source of nutrition and income in resource limited communities. However, one limiting factor is that oyster mushrooms spoil easily and thus a need for simple preservation methods that can help preserve their quality. This study sought to investigate the effect two drying treatments (solar and oven), three blanching treatments (no blanching, water and steam), and four chemical pretreatments (no chemical, lemon juice, vinegar and potassium bisulfite) on oyster mushroom sensory quality. The pretreated dried oyster mushrooms were assessed by a trained panel who rated the mushroom's flavor, texture and appearance attributes on a 174 mm scale. Among the un-blanched samples, those that did not receive any chemical pretreatment and those that were pretreated with lemon juice before drying were found to have better appearance, flavor and were more overally acceptable compared to those with the vinegar and potassium bisulfite treatments. However, when a blanching treatment was included, samples that were treated with potassium bisulfite had superior quality when compared to those treated with lemon juice, vinegar and the control. Solar drying resulted in more browning compared to oven drying. Water blanching resulted in a more fibrous texture compared to steam blanching.

4.2. Introduction

The appearance, aroma, flavor and texture of oyster mushroom are some characteristics that contribute to its sensory quality. Several factors may affect the sensory quality of oyster mushroom and these include inherent genetic factors such as species and strain, as well as

production factors such as substrate. Fresh oyster mushrooms spoil within 3 days at room temperature and can last up to 7 days if refrigerated (Jafri et al., 2013). Some preservation methods that can be employed to extend shelf life include dehydration, canning, and freezing. Preservation may however impact mushroom sensory quality and hence influence consumer acceptability and market value.

Sensory analysis may be done with the use of instruments that measure some mushroom sensory attributes and relating these measurements to perceptions by human senses. Evaluation by a trained or consumer panel allows for direct application of the human senses to determine sensory quality.

4.3. Hypothesis

Drying and pretreatments affect the taste, texture and appearance of oyster mushroom due to the physical and chemical changes that occur during preservation.

4.4. Objective

1. To determine the effect of effect of drying and pretreatments on the appearance, texture, and flavor of oyster mushrooms.

4.5. Materials and methods

4.5.1. Mushroom sample preparation

Mushroom samples were prepared in the same manner as has been previously described in sections 3.4.1. and 3.4.2. Dried mushroom samples were placed in plastic Ziploc bags and refrigerated at 4^{o}C. Sensory analysis commenced a month after drying was completed.

4.5.2. Sensory analysis

Sensory analysis was based on methods described by Liu et al. (2005). Six panelists (4 female and 2 male) within an age range of 20-35 years were trained for oyster mushroom sensory

analysis. The panelists had varying degrees of experience in sensory analysis. The study was authorized by the North Dakota State University Institutional Review Board (protocol #AG13007) and the panelists were given informed consent statements to read and sign. Training was done in three separate sessions using dried oyster mushroom bought from the local grocery stores. The descriptive evaluation form that was later used for this sensory study was developed by the sensory panelists during training using store bought dry mushrooms. Some of the mushrooms used for training were spiked with solutions that had been used as chemical preservatives (lemon juice, vinegar, potassium bisulfite). Some very weak solutions (0.05%) of the preservatives were also included for panelists to taste. In the initial training session, the panelists identified characteristics they perceived with regards to the appearance, flavor and texture of the mushrooms.

All attributes were judged on a 174 mm scale that ranged from barely detectable to extremely high intensity. Panelists identified three appearance attributes (brown color, yellow color and a wrinkled appearance), two texture attributes (rubbery and fibrous) and three flavor attributes (sour, soapy and meaty). Standards, which would mark low and high intensities of each attribute were then identified. For the brown and yellow color, white button mushrooms were used at the barely detectable end of the scale. Portabella mushrooms were used at the high brown intensity while dried yellow oyster mushrooms were used for the high yellow intensity. For the wrinkle appearance, the cap of canned button mushroom was used for the barely detectable end of the scale while some very wrinkled caps from the store bought oyster mushroom were used for high intensity standard. Canned green beans were used for the low fibrous and rubber intensities while stems of cooked oyster mushroom and gummy bears were used for the strong fibrous and rubbery intensities respectively. For the meaty flavor, undiluted and diluted beef

broths were used for the strong and weak intensities respectively. For the soapy flavor, a few drops of dish washing detergent were placed in about 100 ml water and that was used as the strong soapy intensity. A 1:2 and 1:4 dilutions were done to come up with moderately soapy and low soapy intensities. For the sour attribute, a potassium bisulfite solution (0.5%) that had been used during preservation was further diluted 1:5 for the strong solution and 1:10 for the weak intensity solution.

Panelists were given the high and low intensity standards to sample and were asked to mark the intensities on the provided 174 mm scale ranging from weak to strong. There was a discussion as to where the mark should be based on the standard's attribute intensity. Panelists were asked to adjust their perception of the attributes based on the scale and the discussion. To ensure that the panelists had adjusted accordingly, some standards were later given to the panelists to analyze during practice runs. Store bought dried oyster mushrooms were cooked and included in the practice runs. After three training sessions, all the panelists could correctly mark the intensities of the standards on the provided scale.

Dried mushrooms were rehydrated overnight in tap water in the refrigerator then drained and fried in a non-stick skillet. The samples were then transferred into transparent plastic cups and served to the panelists. Samples were served in a predetermined randomized order. Training and analysis of the mushrooms was done in a conference room while preparation of mushrooms for training and analysis was done in a food-processing laboratory at North Dakota State University.

The sensory study was divided into two experiments. The first experiment involved analysis of eight different mushroom treatments to compare the effect of drying method and chemical pretreatment on the sensory quality of oyster mushroom. The four chemical treatments

(lemon juice, potassium bisulfite, vinegar and no chemical) and two drying methods (solar and oven) were combined factorially to give a total of 8 treatments. The second sensory experiment was designed to determine the effect of combining chemical pretreatment, drying method and blanching method on the sensory quality of oyster mushroom. Two chemical treatments (vinegar and potassium bisulfite) and two blanching methods (water and steam) and two drying methods (solar and oven) were combined factorially to give eight treatments (Appendix figure A17).

Samples that had been blanched with no chemical treatment and those that had been blanched followed by treatment with lemon juice were excluded from this sensory analysis as most of them had developed mold (refer to section 3.5.4., Tables 14 and 15). Mushroom from the treatments selected for the sensory study were closely evaluated for mold and if any mold was seen on a mushroom, the whole sample unit was discarded. A randomized complete block design with blocking by day was adopted for both experiments.

4.5.3. Statistical analysis

Mean ratings for each attribute were calculated and analysis of variance was done using Statistical Analysis System (SAS Inst., 1988) and least significant differences were used to separate means.

4.6. Results and Discussion

4.6.1. First experiment

4.6.1.1. Appearance

There was significant chemical pretreatment x drying method interaction ($p<0.05$) on mushroom yellow color (Figures 2(a) and (b), Appendix Table 20). The combination of potassium bisulfite with solar drying and the use of vinegar with either solar or oven drying resulted in lower yellow color ratings.

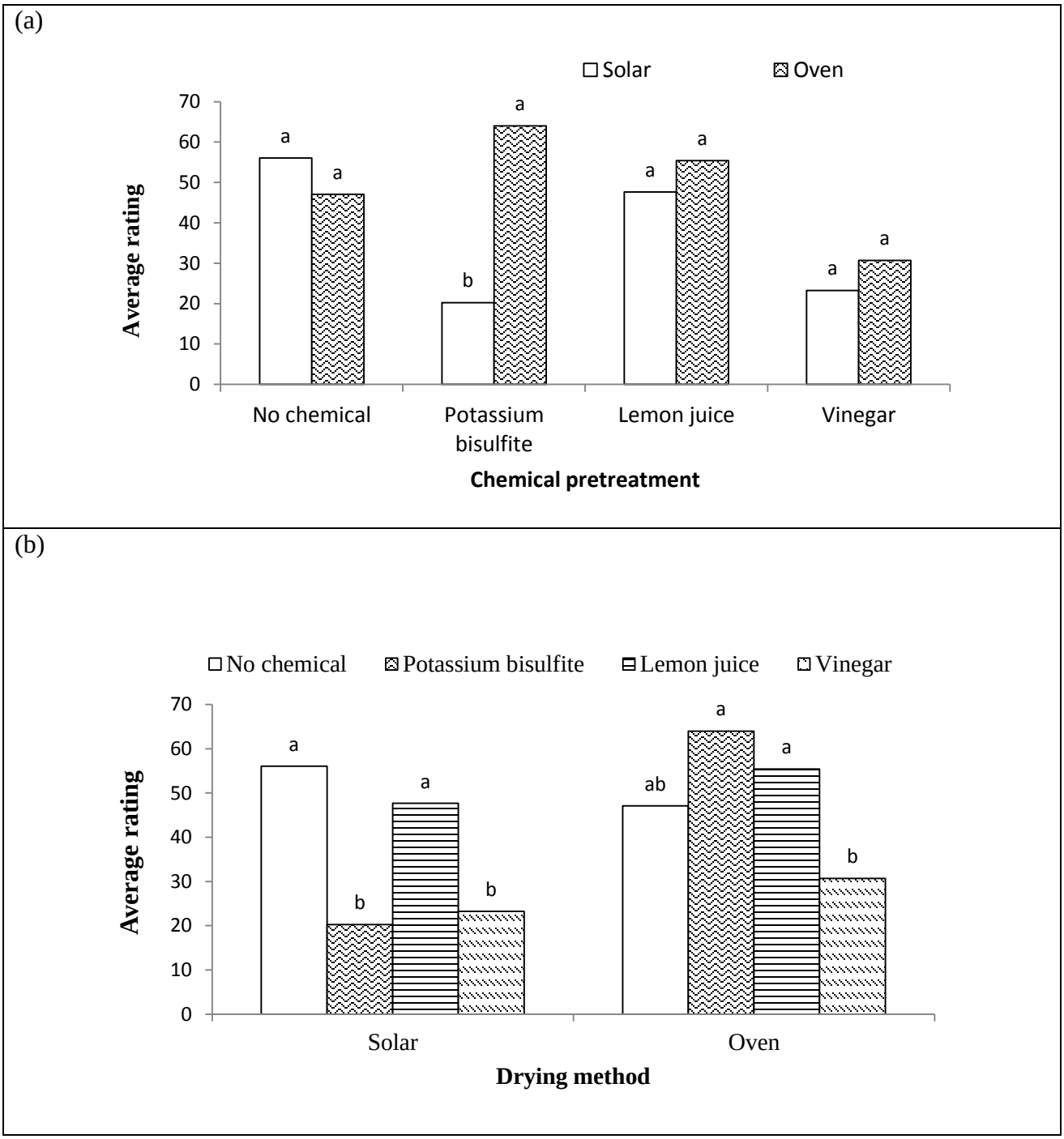


Figure 2. The chemical treatment x drying method interaction for mushroom yellow color ratings is depicted in (a) and (b). Average rating was based on a 174 mm scale.

Solar dried mushrooms had higher yellow color ratings compared to the oven dried ones (Table 16). There were significant differences in yellow color rating among the chemical

pretreatments (Table 17). Vinegar pretreated mushrooms had the least yellow color rating while no differences were observed among the lemon juice, potassium bisulfite and untreated samples.

Table 16. The attributes[a] of oyster mushroom dried using different methods[b].

Drying method	Brown	Yellow
Solar	55.8±6.46 a	49.3±4.64 a
Oven	38.6±3.58 b	36.8±4.79 b

[a] Attributes that were not significantly different were not included in the table. [b]Average rating (mm) ± standard deviations of 2 evaluation sessions (maximum value = 174 mm). Means with the same letter within the same column were not significantly different from each other ($p \leq 0.05$).

Table 17. The attributes[a] of dehydrated oyster mushroom with different chemical pretreatments[b].

Chemical	Brown	Yellow	Wrinkle	Sour	Soapy	Overall
No chemical	17.3±2.3b	51.6±7.0a	40.9±7.1a	9.3±1.9b	7.8±1.3b	82.0±5.8a
KBS[c]	71.1±6.9a	42.1±6.8a	21.6±3.1b	28.0±5.7a	17.4±4.7a	31.9±4.9b
Lemon juice	23.3±2.9b	51.5±7.5a	38.7±5.4a	11.5±1.9b	7.3±1.2b	75.5±7.2a
Vinegar	77.2±6.9a	27.0±4.4b	19.4±2.4b	18.1±4.2b	17.0±4.0a	31.2±4.5b

[a] Attributes that were not significantly different were not included in the table. [b]Average rating (mm) ± standard deviations of 2 evaluation sessions (maximum value = 174 mm), means with the same letter within the same column were not significantly different ($p \leq 0.05$). [c]KBS means potassium bisulfite.

There was significant chemical pretreatment x drying method interaction ($p<0.05$) on mushroom brown color ratings (Figures 3 (a) and (b); Appendix Table 21.). Combining vinegar and potassium bisulfite with either of the drying methods resulted in higher brown color ratings, with the more browning observed on solar dried mushrooms. Lemon juice and no chemical treatment combined with either solar or oven drying resulted in the least browning (Table 14).

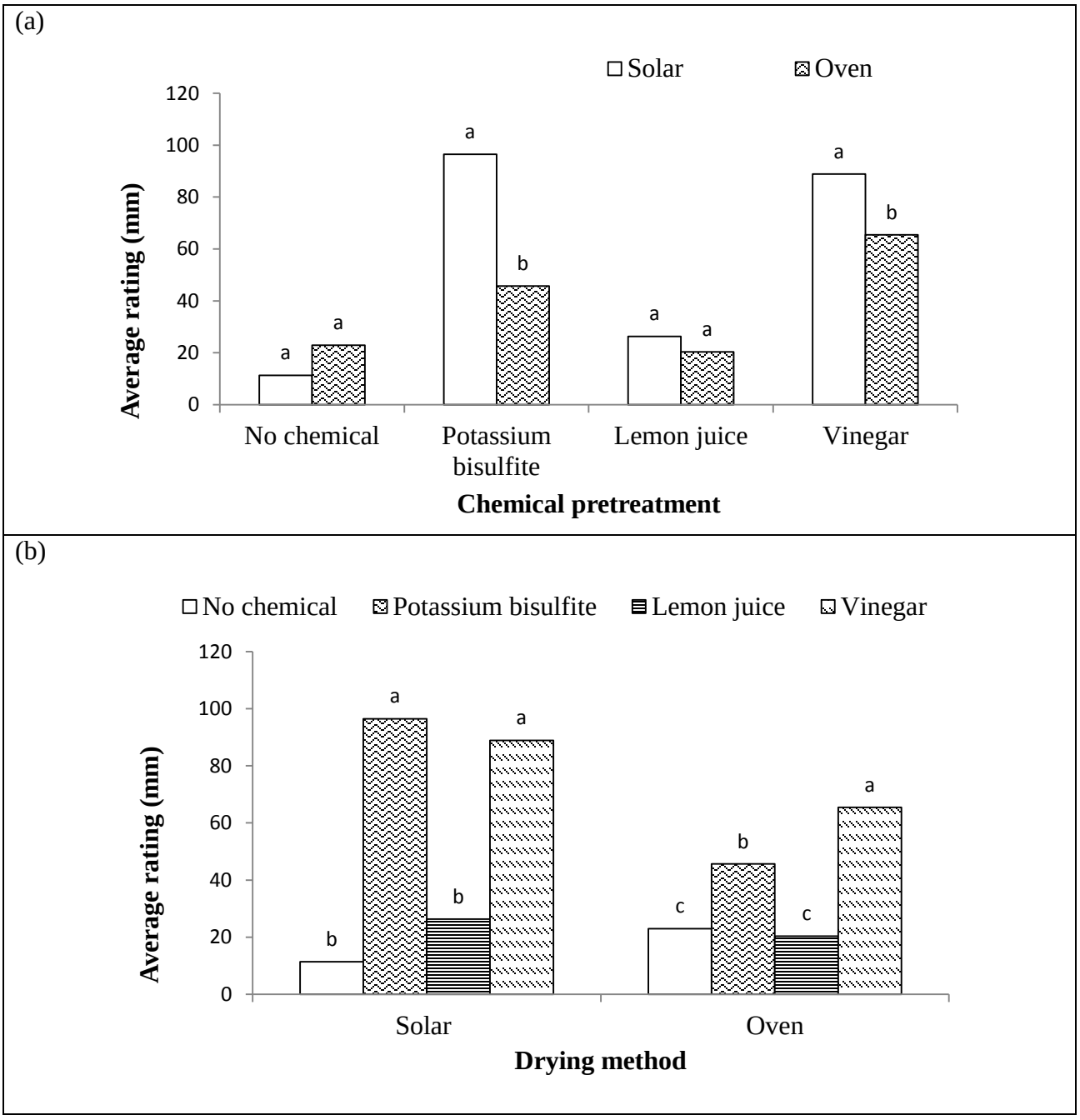


Figure 3. The chemical treatment x drying method interaction for mushroom brown color ratings is depicted in (a) and (b). Average rating was based on a 174 mm scale.

Solar dried mushrooms had higher browning ratings compared to oven drying (Table 13). Visual comparisons of fresh oyster mushroom supports color differences compared to solar and oven dried mushroom with no blanching and no chemical pretreatment (Figures 4(a), (b),

and (c). There was a decrease in white color with an increase in the yellow and brown color intensities. The higher brown and yellow color ratings (Table 13) observed with solar drying could be as a result of Maillard browning. Solar drier temperatures fluctuated and at peak day temperatures, they were often close to 80^{o}C (Appendix Tables A1-A10). Oven drying temperatures were maintained at 43 ^{o}C throughout the drying process hence less browning was observed (Appendix Tables A11-A14). In line with these observations, other workers reported that high drying temperature results in more pigmentation hence a darker product (Kotwaliwale et al. 2007; Sturm et al. 2014).

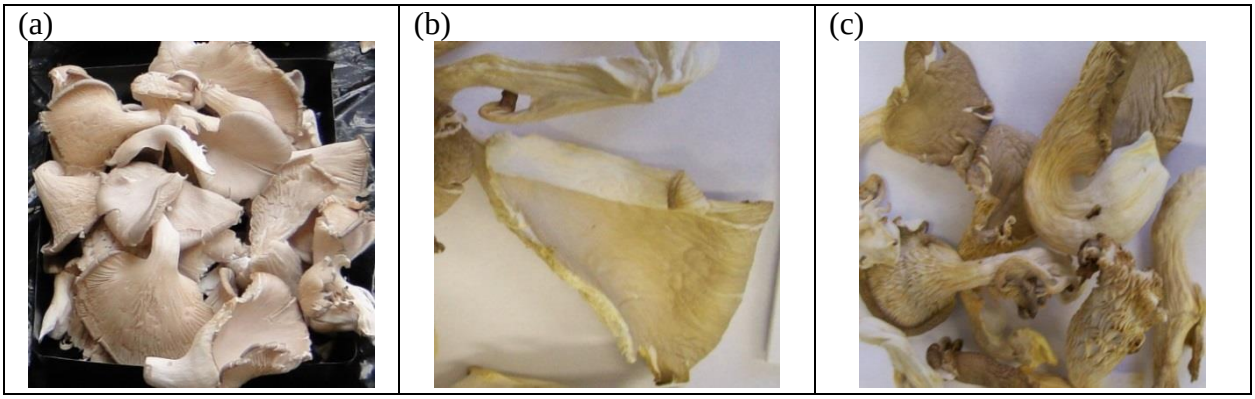


Figure 4. Fresh, oven dried and solar dried oyster mushrooms are shown in (a), (b) and (c) respectively. The dried mushrooms shown did not receive any blanching or chemical pretreatments.

There were significant differences ($P<0.05$) in the wrinkled appearance of mushrooms that received different chemical treatments (Table 14; Appendix Table 22). Vinegar and potassium bisulfite treated samples had the least amount of wrinkling when compared to lemon juice and untreated samples.

4.6.1.2. Flavor

Meaty flavor ranged from 5-106 mm with an average of 40 mm across all samples. There were no differences in the meaty flavor attribute observed among all the treatments (Appendix table 23). There were significant differences ($P<0.05$) in the sour flavor attribute among the

chemical pretreatments (Table 14; Appendix Table 24). The sour rating across all treatments was generally low. Mushrooms treated with potassium bisulfite were observed to have the highest sour rating (28.0 ± 3.5 mm). This was not surprising since the panelists had initially identified the sour taste when sampling the weak potassium bisulfite solution during training. This would indicate that potassium bisulfite taste carried over into the mushroom flavor.

There were significant differences ($p<0.05$) n the soapy flavor rating among the different chemical pretreatments (Table 14; Appendix Table 25). Mushrooms treated with potassium bisulfite and vinegar were observed to have higher soapy ratings. The soap used as a standard for this attribute was a potassium hydroxide based liquid soap which would explain why mushroom that was treated with potassium bisulfite would present a soapy flavor. However, it is not clear why samples treated with vinegar would have a soapy flavor.

4.6.1.3. Texture

There were no significant differences ($P<0.05$) in the rubbery fibrous texture attributes of dried mushroom across all treatments (Appendix Tables 26 and 27 respectively).

4.6.1.4. Overall

There were significant differences ($P<0.05$) in the overall acceptability of mushrooms that received different chemical pretreatments (Table 14; Appendix Table 28). Overall acceptability was highest for the untreated and the lemon juice treated samples. The same treatments were associated with a lighter color and better flavor, which would explain why they were the most preferred treatments.

4.6.2. Second experiment

4.6.2.1. Texture

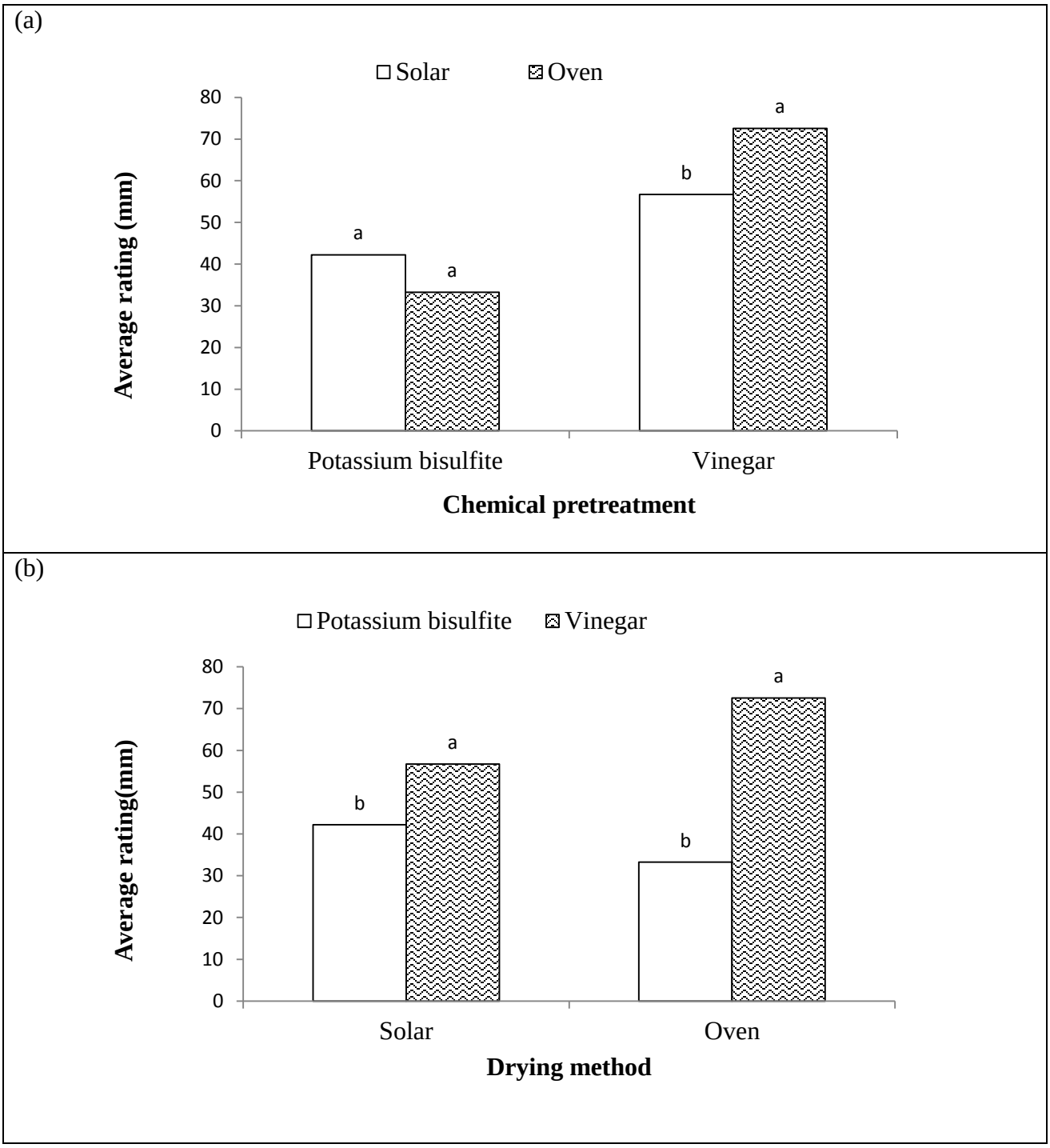
There was significant chemical pretreatment x drying method x blanching method interaction for the fibrous attribute (Table 18; Appendix Table 29). Among all the potassium bisulfite samples, there was no difference despite the drying and blanching methods. For samples treated with vinegar, a higher fibrous intensity was observed in mushrooms that had received a combination of oven drying and water blanching compared to oven drying and solar drying.

Table 18. Mean rating for oyster mushroom fibrous attribute[a] .

Drying method	Blanching method	Chemical pretreatment	Mean
Solar	Water	KBS[b]	75.1±6.2 ab
Solar	Water	Vinegar	69.7±6.8 ab
Solar	Steam	KBS	44.9±5.8 b
Solar	Steam	Vinegar	63.2±8.5 ab
Oven	Water	KBS	57.4±8.6 b
Oven	Water	Vinegar	81.6±8.6 a
Oven	Steam	KBS	75.1±9.4 ab
Oven	Steam	Vinegar	50.9±7.3 b

[a]Average rating (mm) ± standard deviations of 2 evaluation sessions (maximum value = 174 mm), means with the same letter within the same column were not significantly different ($p \leq 0.05$). [b]KBS means potassium bisulfite.

There was significant chemical pretreatment x drying method interaction for the rubbery attribute (Figures 5 (a) and (b); Appendix Table 30). When compared to vinegar, mushroom treated with potassium bisulfite had a lower rubbery rating with both oven and solar drying methods. Samples that were water blanched, treated with vinegar followed by oven drying had the highest rubbery rating.



Figures 5. The chemical treatment x drying method interaction for mushroom rubbery ratings is depicted in (a) and (b). Average rating was based on a 174 mm scale.

Blanching treatments resulted in a difference in the mushroom's fibrous attribute (Table 19). Water blanching resulted in more fibrous mushroom texture when compared to steam

blanching. Several studies (Czapski and Szudyga, 2000; Zivanovic and Buescher, 2004; Kotwaliwale et al., 2007) have reported a negative change in mushroom texture following blanching. The heat from blanching causes a disruption of protein and membrane structure hence a loss of water and some soluble cell components thus contributing to the textural changes (Zivanovic and Buescher, 2004). In these previous studies, blanching was done by immersing samples in hot water for varying periods of time. In the current study, a distinction is made between water (immersing samples in hot water) and steam blanching, with the later resulting in better texture.

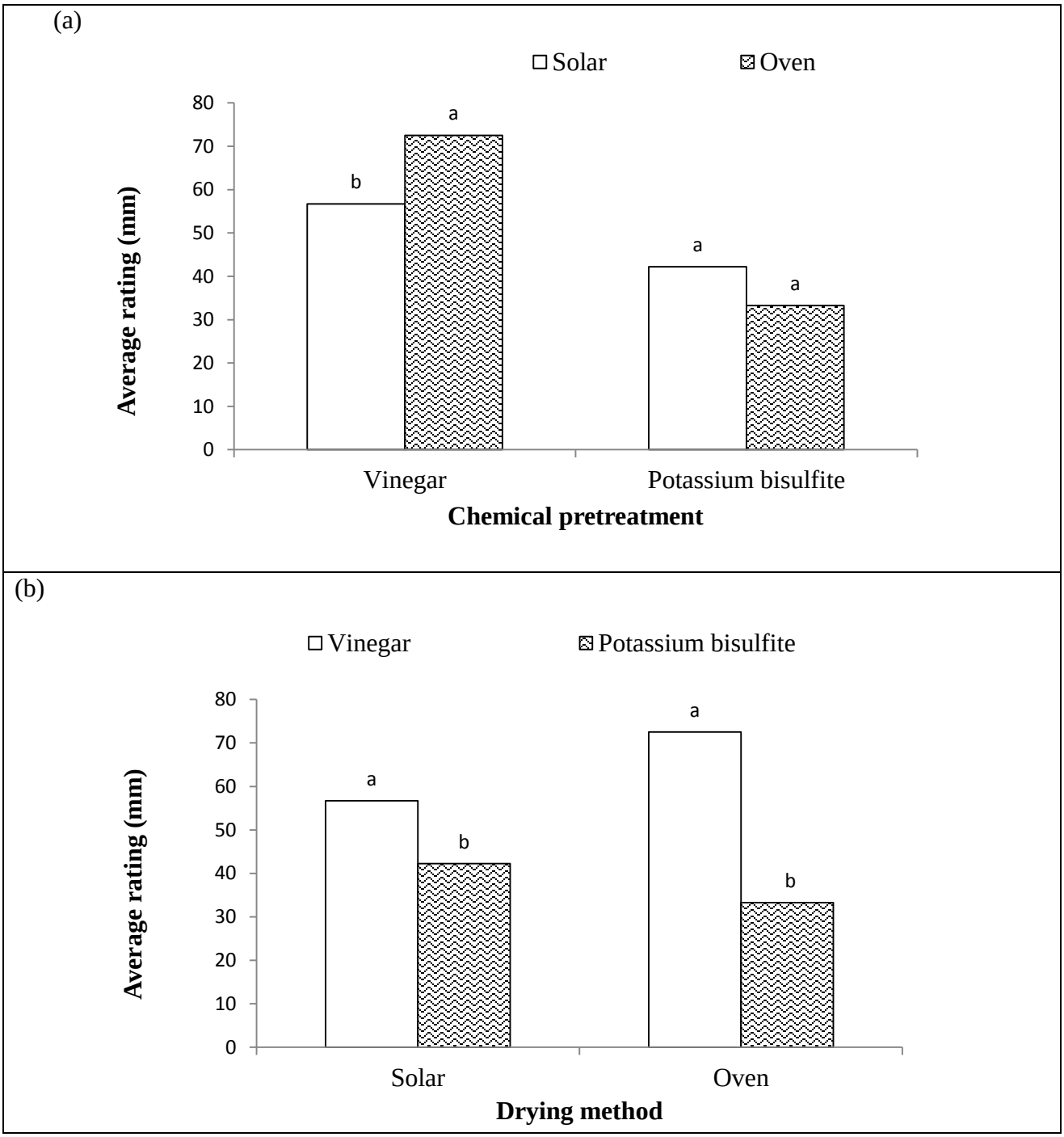
Table 19. The attributes[a] of dehydrated oyster mushroom with different blanching pretreatments[b].

Blanching method	Brown	Sour	Fibrous	Overall
Water blanching	36.6±3.6 b	10.9±2.0 b	70.94±3.9 a	68.8±4.3 a
Steam blanching	65.8±4.5 a	17.0±2.7 a	58.52±4.2 b	50.5±4.7 b

[a] Attributes that were not significantly different were not included in the table. [b]Average rating (mm) ± standard deviations of 2 evaluation sessions (maximum value = 174 mm). Means with the same letter within the same column were not significantly different ($p \leq 0.05$).

4.6.2.2. Appearance

There was significant chemical pretreatment x drying method interaction ($P<0.05$) on the brown color attribute (Figure 6 (a) and (b); Appendix Table 31). Vinegar treatment produced mushrooms with higher brown color intensity in both solar and oven dried mushrooms (Table 20). Vinegar treatment followed by oven drying resulted in higher browning. More browning was observed with vinegar treatment compared to potassium bisulfite (Table 20.) which would suggest that vinegar is not as efficient as potassium bisulfite in optimizing dried mushroom color.



Figures 6. The chemical treatment x drying method interaction for mushroom brown color ratings is depicted in (a) and (b). Average rating was based on a 174 mm scale.

Table 20. The attributes[a] of dehydrated oyster mushrooms with different chemical pretreatments[b].

Chemical pretreatment	Brown	Sour	Wrinkle	Overall
Potassium bisulfite	37.7±4.4 b	8.6±1.5 b	21.1± 2.3 a	69.8±4.7 a
Vinegar	64.6±3.9 a	19.4±2.9 a	27.1±2.6 b	49.5±4.2 b

[a]Attributes that were not significantly different were not included in the table. [b]Average rating (mm) ± standard deviations of 2 evaluation sessions (maximum value = 174 mm). Means with the same letter within the same column were not significantly different from each other ($p \leq 0.05$).

There were significant differences in the effect of blanching method on the brown color ratings (Table 19). Steam blanching resulted in higher ratings for brown color compared to water blanching. In comparing the blanching methods, steam blanched mushrooms were found to have more browning than water blanching. Since mushroom browning is mostly attributed to polyphenol oxidase activity (Rodrı´guez-Lo´pez et al., 1999), it is possible that water blanching was more effective in deactivating the enzyme compared to steam blanching. There were no significant differences ($P<0.05$) in the yellow color appearance among the different treatments (Appendix Table 32).

There were significant differences ($P<0.05$) in the wrinkled appearance of mushrooms that received different chemical treatments (Table 20; Appendix Table 33). Mushrooms treated with vinegar had a more wrinkled appearance compared to those treated with potassium bisulfite.

4.6.2.3. Flavor

There were significant differences ($P<0.05$) in the mushroom sour rating among the different chemical pretreatments (Table 20; Appendix Table 34). Samples treated with vinegar were found to have higher sour ratings compared to those treated with potassium bisulfite (Table 20). The sour taste was probably carried over from the chemical pretreatments. This was in

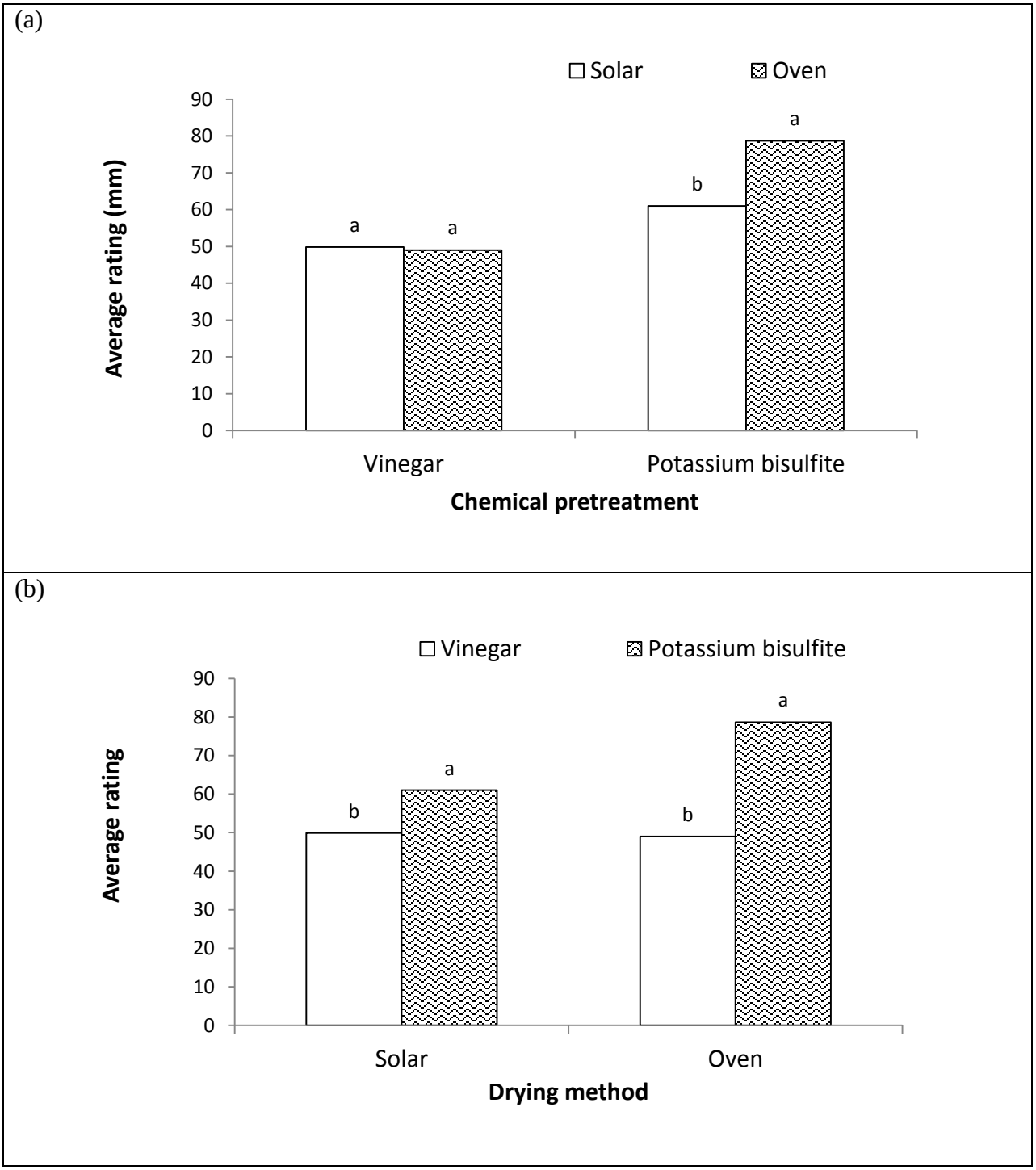
contrast to the result obtained from the first sensory experiment where potassium bisulfite treated mushrooms had a higher sour taste intensity. Considering that ratings were done on a scale of 0-174 mm, the average sour ratings were generally low with both the vinegar and potassium bisulfite treated samples (19.4±2.9 and 8.6±1.5 mm, respectively). While weak organic acids such as acetic acid found in vinegar maybe helpful in preserving some quality traits, they may have a negative effect on taste, (Iyengar and McEvily, 1992). However, any hint of sour flavor in mushroom is not desirable. There were no significant differences ($P<0.05$) in the meaty and soapy flavor attributes across all treatments (Appendix Tables 35 and 36 respectively).

4.6.2.4. Overall acceptability

There was significant chemical pretreatment x drying method interaction ($P<0.05$) for oyster mushroom overall acceptability ratings (Figure 7 (a) and (b); Appendix Table 37). Overall acceptability of mushroom treated with vinegar was lower than that of mushroom treated with potassium bisulfite, for both solar and oven dried samples. The combination of potassium bisulfite with oven drying resulted in the highest ratings for overall acceptability. The same combination of treatments had lower rubbery (Figure 5 (a) and (b)) and browning ratings (Figure 6 (a) and (b)), which would indicate that the treatments that resulted in better appearance and better texture had higher overall acceptability ratings.

Mushrooms that had been water blanched were more acceptable compared to those that were steam blanched (Table 19). Water blanching was found to result in better color preservation but higher fibrous texture (Table 19). These observations would suggest that appearance had more impact on overall acceptability when compared to texture. There was a significant difference ($P<0.05$) in the overall acceptability of mushrooms dehydrated using solar and oven

drying (Table 21). The overall acceptability of mushrooms that had been oven dried was greater than those that had been solar dried.



Figures 7. The chemical treatment x drying method interaction for mushroom overall acceptability ratings is depicted in (a) and (b). Average rating was based on a 174 mm scale.

Table 21. The attributes[a] of oven and solar dried oyster mushrooms[b].

Drying method	Overall
Solar	55.4±4.7 a
Oven	63.9±4.6 b

[a] Attributes that were not significantly different were not included in the table. [b]Average rating (mm) ± standard deviations of 2 evaluation sessions (maximum value = 174 mm). Means with the same letter within the same column were not significantly different from each other ($p \leq 0.05$).

4.7. Conclusion

Drying and pretreatments were found to affect the sensory quality of oyster mushroom. When mushrooms received only chemical pretreatment before drying without any blanching, better quality was associated with mushrooms treated with lemon juice and no chemical treatments. The effect of vinegar and potassium bisulfite in combination with blanching treatment were significant. Potassium bisulfite resulted in better quality. Solar drying resulted in more browning compared to oven drying. Steam blanching resulted in better textural quality when compared to water blanching. Drying and pretreatments altered the appearance, texture and flavor of oyster mushrooms with some treatments being more preferable than others. There is a need to select a combination of preservation treatments that maximize the sensory quality of oyster mushroom.

4.8. References

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APPENDIX

Table A1. Partial ANOVA for dried oyster mushroom moisture content.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Expt	1	4.3845299	4.3845299	0.02	0.9143
rep(Expt)	4	389.1035389	97.2758847	1.50	0.3529
Dry	1	29.7626003	29.7626003	0.13	0.7813
Expt*dry	1	232.6147013	232.6147013	3.11	0.1814
Expt*rep*dry	4	260.0690126	65.0172532	2.56	0.0440
Blanch	2	181.4115731	90.7057866	7.10	0.1234
Expt*blanch	2	25.5469950	12.7734975	0.26	0.7878
dry*blanch	2	25.6581311	12.8290655	0.39	0.7202
Expt*dry*blanch	2	66.0442079	33.0221039	1.33	0.3335
Chemical	3	210.5397976	70.1799325	5.05	0.1083
Expt*chemical	3	41.7161759	13.9053920	0.33	0.8069
dry*chemical	3	185.8363819	61.9454606	2.34	0.2513
Expt*dry*chemical	3	79.3273044	26.4424348	1.06	0.4323
blanch*chemical	6	203.3289937	33.8881656	0.83	0.5845
Expt*blanch*chemical	6	243.8417458	40.6402910	1.63	0.2834
dry*blanch*chemical	6	226.4586955	37.7431159	1.52	0.3132
Expt*dry*blanc*chemi	6	149.4274564	24.9045761	0.98	0.4431
Error	88	2234.109145	25.387604		
Corrected Total	143	4799.467814			

Table A2. Partial ANOVA for dried oyster mushroom total phenolic content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment (ext)	1	4.4572516	4.4572516	0.66	0.5198
Rep (expt)	4	5.1597610	1.2899403	0.67	0.6467
Drying	1	4.8582796	4.8582796	4.30	0.2859
Expt*drying	1	1.1285695	1.1285695	0.43	0.6330
Expt*rep*drying	4	7.7115758	1.9278939	1.21	0.3112
Blanching	2	537.1853673	268.5926837	60.36	0.0163
Expt*blanch	2	8.8999865	4.4499932	2.97	0.5495
Drying*blanch	2	0.1860553	0.0930276	0.03	0.9668
Expt*drying*blanch	2	5.4185388	2.7092694	1.09	0.3934
Chemical	3	122.7439795	40.9146598	7.62	0.0647
Expt*chemical	3	16.1049444	5.3683148	6.20	0.6042
Drying*chemical	3	20.3978210	6.7992737	3.27	0.1782
Expt*drying*chemical	3	6.2358931	2.0786310	0.84	0.5198
Blanch*chemical	6	249.9509839	41.6584973	32.99	0.0002
Expt*blanch*chemical	6	7.5771867	1.2628644	0.51	0.7835
Drying*blanch*chemical	6	21.6692216	3.6115369	1.46	0.3291
Expt*drying*blanch*chemical	6	14.853810	2.475635	1.56	0.1692
Error	88	139.892830	1.589691		
Corrected total	143	1172.132128			

Table A3. Partial ANOVA for dried oyster mushroom total flavonoid content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment (expt)	1	15.9995055	15.9995055	1.67	0.4228
Rep (expt)	4	3.7873510	0.9468377	0.93	0.5263
Drying	1	29.9883972	29.9883972	4.11	0.2919
Expt*dry	1	7.3045740	7.3045740	3.47	0.6759
Expt*rep*dry	4	4.0632061	1.0158015	1.78	0.1398
Blanch	2	132.9112189	66.4556095	72.51	0.0136
Expt*blanch	2	1.8330574	0.9165287	0.27	0.8353
Drying*blanch	2	11.0060954	5.5030477	0.95	0.5127
Expt*drying*blanch	2	11.5792232	5.7896116	0.99	0.4257
Chemical	3	96.1128448	32.0376149	4.89	0.1126
Expt*chemical	3	19.6633061	6.5544354	-9.56	.
Drying*chemical	3	3.6863592	1.2287864	0.71	0.6062
Expt*drying*chemical	3	5.1709200	1.7236400	0.29	0.8287
Blanching*chemical	6	78.6932268	13.1155378	3.80	0.0645
Expt*blanching*chemical	6	20.7114940	3.4519157	0.59	0.7319
Drying*blanching*chemical	6	14.9020428	2.4836738	0.42	0.8400
Expt*drying*blanch*chemical	6	35.1660693	5.8610116	10.27	<.0001
Error	88	50.1986420	0.5704391		
Corrected Total	143	544.8762738			

Table A4. Partial ANOVA for dried oyster mushroom ergothioneine content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment (expt)	1	0.21372577	0.21372577	3.09	0.4134
Rep (expt)	4	0.02371577	0.00592894	0.68	0.6397
Drying	1	0.00002706	0.00002706	0.00	0.9877
Expt*drying	1	0.07193650	0.07193650	1.81	0.3395
Expt*rep*drying	4	0.03473098	0.00868274	0.69	0.5982
Blanching	2	0.91386805	0.45693402	21.79	0.0439
Expt*blanch	2	0.04193104	0.02096552	0.42	0.6950
dry*blanch	2	0.00640561	0.00320280	0.08	0.9266
Expt*drying*blanch	2	0.08090820	0.04045410	2.56	0.1567
Chemical	3	0.55997052	0.18665684	3.91	0.1462
Expt*chemical	3	0.14328069	0.04776023	1.69	0.3386
Dry*chemical	3	0.08052418	0.02684139	1.42	0.3901
Expt*drying*chemical	3	0.05670792	0.01890264	1.20	0.3874
Blanch*chemical	6	0.27325735	0.04554289	1.81	0.2446
Expt*blanch*chemical	6	0.15109329	0.02518222	1.60	0.2921
Drying*blanch*chemical	6	0.11183779	0.01863963	1.18	0.4223
Expt*drying*blanch*chemical	6	0.09464305	0.01577384	1.26	0.2839
Error	88	1.10118192	0.01251343		
Corrected total	143	3.98357844			

Table A5. Partial ANOVA for dried oyster mushroom hydrophilic ORAC values.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	1208.358754	1208.358754	0.92	0.4737
Rep (expt)	4	521.228701	130.307175	1.62	0.3265
Drying	1	1897.089994	1897.089994	1.72	0.4152
Expt*drying	1	1106.048118	1106.048118	-17.01	.
Expt*rep*drying	4	322.408087	80.602022	1.66	0.1670
Blanching	2	45.509552	22.754776	3.92	0.2034
Expt*blanch	2	11.617354	5.808677	-0.10	.
Dry*blanch	2	10.025426	5.012713	0.66	0.6030
Expt*drying*blanch	2	15.230038	7.615019	0.06	0.9390
Chemical	3	625.526106	208.508702	1.88	0.3087
Expt*chemical	3	332.859372	110.953124	-2.12	.
Drying*chemical	3	245.642037	81.880679	5.55	0.0966
Expt*drying*chemical	3	44.292785	14.764262	0.12	0.9430
Blanching*chemical	6	357.666992	59.611165	1.13	0.4420
Expt*blanch*chemical	6	315.918905	52.653151	0.44	0.8298
Drying*blanch*chemical	6	271.215950	45.202658	0.38	0.8696
Expt*drying*blanc*chemi	6	718.808722	119.801454	2.46	0.0300
Error	88	4278.99510	48.62494		
Corrected total	143	12178.61991			

Table A6. Partial ANOVA for dried oyster mushroom total ORAC values.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Expt	1	1539.504061	1539.504061	0.92	0.4753
rep(Expt)	4	649.290089	162.322522	1.75	0.3013
Dry	1	2422.661785	2422.661785	1.71	0.4160
Expt*dry	1	1420.205371	1420.205371	-18.25	.
Expt*rep*dry	4	371.904321	92.976080	1.59	0.1852
Blanch	2	47.131932	23.565966	6.27	0.1375
Expt*blanch	2	7.512329	3.756164	-0.05	.
dry*blanch	2	13.118050	6.559025	0.97	0.5075
Expt*dry*blanch	2	13.518475	6.759237	0.05	0.9541
Chemical	3	764.712746	254.904249	2.00	0.2918
Expt*chemical	3	382.314294	127.438098	-2.09	.
dry*chemical	3	367.310489	122.436830	5.21	0.1043
Expt*dry*chemical	3	70.512842	23.504281	0.16	0.9164
blanch*chemical	6	472.683835	78.780639	1.35	0.3632
Expt*blanch*chemical	6	350.737063	58.456177	0.41	0.8494
dry*blanch*chemical	6	327.363063	54.560510	0.38	0.8667
Expt*dry*blanc*chemi	6	857.128432	142.854739	2.44	0.0317
Error	88	5159.69470	58.63289		
Corrected Total	143	15063.32104			

Table A7. Partial ANOVA for dried oyster mushroom lipophilic ORAC values.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment (expt)	1	20.02178066	20.02178066	0.93	0.4896
Rep (expt)	4	11.39056486	2.84764121	3.41	0.1309
Drying	1	32.09170566	32.09170566	1.64	0.4224
Expt*drying	1	19.60536448	19.60536448	124.42	0.9398
Expt*rep*drying	4	3.34023665	0.83505916	0.74	0.5642
Blanch	2	1.21529344	0.60764672	1.62	0.3819
Expt*blanch	2	0.75088482	0.37544241	-0.34	.
Dry*blanch	2	1.00753311	0.50376655	17.70	0.0535
Expt*drying*blanch	2	0.05692248	0.02846124	0.02	0.9832
Chemical	3	9.95805890	3.31935297	5.61	0.0952
Expt*chemical	3	1.77522108	0.59174036	0.61	0.7657
Drying*chemical	3	15.72004501	5.24001500	2.50	0.2359
Expt*drying*chemical	3	6.29285622	2.09761874	1.25	0.3720
Blanch*chemical	6	12.80713080	2.13452180	3.82	0.0638
Expt*blanch*chemical	6	3.35172593	0.55862099	0.33	0.8968
Drying*blanch*chemical	6	4.82240496	0.80373416	0.48	0.8040
Expt*drying*blanch*chemical	6	10.07012151	1.67835359	1.50	0.1887
Error	88	98.7009566	1.1216018		
Corrected Total	143	252.2091830			

Table A8. Partial ANOVA for dried oyster mushroom Na content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	4324.4401	4324.4401	2.25	0.4639
Rep (expt)	4	3053.1798	763.2949	6.80	0.0451
Drying	1	2203.5131	2203.5131	222.60	0.0426
Expt*drying	1	9.8989	9.8989	0.01	0.9443
Expt*rep*drying	4	449.0931	112.2733	0.16	0.9567
Blanching	2	66978.0546	33489.0273	140.86	0.0070
Expt*blanch	2	475.4896	237.7448	0.13	0.8798
Drying*blanch	2	1405.8506	702.9253	0.48	0.6769
Expt*drying*blanch	2	2945.7773	1472.8887	8.25	0.0190
Chemical	3	420449.8054	140149.9351	38.65	0.0067
Expt*chemical	3	10878.0669	3626.0223	3.18	0.1299
Drying*chemical	3	2583.5865	861.1955	1.02	0.4928
Expt*drying*chemical	3	2525.9081	841.9694	4.71	0.0509
Blanching*chemical	6	24135.7900	4022.6317	8.41	0.0102
Expt*blanch*chemical	6	2870.9723	478.4954	2.68	0.1278
Drying*blanch*chemical	6	2436.9157	406.1526	2.27	0.1703
Expt*drying*blanc*chemical	6	1071.6363	178.6060	0.26	0.9545
Error	88	60746.7566	690.3041		
Corrected total	143	608577.5924			

Table A9. Partial ANOVA for dried oyster mushroom S content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	1079675.3	1079675.3	0.96	0.7369
Rep (expt)	4	1143919.2	285979.8	4.20	0.0968
Drying	1	82447.7	82447.7	0.05	0.8612
Expt*drying	1	1679098.8	1679098.8	1.20	0.4328
Expt*rep*drying	4	272424.0	68106.0	0.37	0.8312
Blanching	2	35011173.2	17505586.6	17.71	0.0534
Expt*blanch	2	1976359.2	988179.6	0.81	0.5422
Drying*blanch	2	1361825.5	680912.8	1.62	0.3814
Expt*drying*blanch	2	839643.9	419821.9	0.50	0.6322
Chemical	3	729379723.4	243126574.5	174.17	0.0007
Expt*chemical	3	4187706.2	1395902.1	0.51	0.6963
Drying*chemical	3	570477.1	190159.0	0.10	0.9561
Expt*drying*chemical	3	5834573.7	1944857.9	2.30	0.1777
Blanching*chemical	6	78418218.1	13069703.0	7.96	0.0117
Expt*blanch*chemical	6	9847157.1	1641192.8	1.94	0.2206
Drying*blanch*chemical	6	2952158.8	492026.5	0.58	0.7373
Expt*drying*blanc*chemical	6	5083901.6	847316.9	4.57	0.0004
Error	88	16306570.5	185301.9		
Corrected total	143	896403874.9			

Table A10. Partial ANOVA for dried oyster mushroom K content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	132889201	132889201	-78.02	.
Rep (expt)	4	14439691	3609923	3.13	0.1475
Drying	1	4321301	4321301	0.17	0.7484
Expt*drying	1	24824920	24824920	0.72	0.4973
Expt*rep*dry	4	4613692	1153423	0.28	0.8916
Blanch	2	2549298452	1274649226	154.60	0.0064
Expt*blanch	2	16490078	8245039	0.21	0.8234
Drying*blanch	2	8671439	4335719	0.16	0.8605
Expt*drying*blanch	2	53496262	26748131	1.47	0.3015
Chemical	3	2196372604	732124201	23.66	0.0137
Expt*chemical	3	92820912	30940304	0.75	0.5842
Drying*chemical	3	5111843	1703948	0.06	0.9779
Expt*dry*chemical	3	86169370	28723123	1.58	0.2889
Blancing*chemical	6	422225130	70370855	2.28	0.1697
Expt*blanch*chemical	6	185250675	30875113	1.70	0.2673
Drying*blanch*chemical	6	18720586	3120098	0.17	0.9750
Expt*drying*blanc*chemi	6	108868684	18144781	4.37	0.0007
Error	88	365330901	4151488		
Corrected total	143	6306387503			

Table A11. Partial ANOVA for dried oyster mushroom Mg content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	425089.076	425089.076	-24.23	.
Rep (expt)	4	25879.529	6469.882	1.18	0.4370
Drying	1	3448.205	3448.205	0.74	0.5485
Expt*drying	1	4682.362	4682.362	0.18	0.7440
Expt*rep*drying	4	21861.541	5465.385	0.61	0.6548
Blanching	2	1136517.768	568258.884	54.86	0.0179
Expt*blanch	2	20717.363	10358.682	0.26	0.7927
Drying*blanch	2	3580.172	1790.086	0.06	0.9474
Expt*drying*blanch	2	64421.000	32210.500	1.72	0.2568
Chemical	3	417806.526	139268.842	6.15	0.0850
Expt*chemical	3	67924.188	22641.396	0.94	0.5437
Drying*chemical	3	7123.693	2374.564	0.15	0.9239
Expt*drying*chemical	3	47823.132	15941.044	0.85	0.5147
Blanching*chemical	6	127125.096	21187.516	0.79	0.6089
Expt*blanch*chemical	6	160898.024	26816.337	1.43	0.3370
Drying*blanch*chemical	6	75663.193	12610.532	0.67	0.6784
Expt*drying*blanc*chemical	6	112364.043	18727.340	2.10	0.0613
Error	88	785399.541	8924.995		
Corrected total	143	3522935.323			

Table A12. Partial ANOVA for dried oyster mushroom Na content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	4324.4401	4324.4401	2.25	0.4639
Rep (expt)	4	3053.1798	763.2949	6.80	0.0451
Drying	1	2203.5131	2203.5131	222.60	0.0426
Expt*drying	1	9.8989	9.8989	0.01	0.9443
Expt*rep*drying	4	449.0931	112.2733	0.16	0.9567
Blanching	2	66978.0546	33489.0273	140.86	0.0070
Expt*blanch	2	475.4896	237.7448	0.13	0.8798
Drying*blanch	2	1405.8506	702.9253	0.48	0.6769
Expt*drying*blanch	2	2945.7773	1472.8887	8.25	0.0190
Chemical	3	420449.8054	140149.9351	38.65	0.0067
Expt*chemical	3	10878.0669	3626.0223	3.18	0.1299
Drying*chemical	3	2583.5865	861.1955	1.02	0.4928
Expt*drying*chemical	3	2525.9081	841.9694	4.71	0.0509
Blanching*chemical	6	24135.7900	4022.6317	8.41	0.0102
Expt*blanch*chemical	6	2870.9723	478.4954	2.68	0.1278
Drying*blanch*chemical	6	2436.9157	406.1526	2.27	0.1703
Expt*drying*blanc*chemical	6	1071.6363	178.6060	0.26	0.9545
Error	88	60746.7566	690.3041		
Corrected total	143	608577.5924			

Table A13. Partial ANOVA for dried oyster mushroom P content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	41877185.03	41877185.03	1576.21	0.9978
Rep (expt)	4	1343105.37	335776.34	2.12	0.2421
Drying	1	227467.68	227467.68	149.52	0.0519
Expt*drying	1	1521.32	1521.32	0.02	0.9928
Expt*rep*drying	4	632969.63	158242.41	0.35	0.8449
Blanching	2	39609238.78	19804619.39	18.48	0.0513
Expt*blanch	2	2142781.72	1071390.86	0.63	0.6193
Drying*blanch	2	1349022.91	674511.46	0.61	0.6195
Expt*drying*blanch	2	2195953.06	1097976.53	0.79	0.4979
Chemical	3	11464209.67	3821403.22	3.34	0.1739
Expt*chemical	3	3427783.94	1142594.65	0.90	0.5959
Drying*chemical	3	901674.97	300558.32	0.45	0.7381
Expt*drying*chemical	3	2023950.14	674650.05	0.48	0.7065
Blanching*chemical	6	16144884.95	2690814.16	1.35	0.3627
Expt*blanch*chemical	6	11967770.25	1994628.37	1.43	0.3387
Drying*blanch*chemical	6	5719905.68	953317.61	0.68	0.6733
Expt*drying*blanc*chemical	6	8391170.42	1398528.40	3.07	0.0089
Error	88	40031345.9	454901.7		
Corrected total	143	190475088.1			

Table A14. Partial ANOVA for dried oyster mushroom Ca content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	2584.78709	2584.78709	0.37	0.6139
Rep (expt)	4	9045.98090	2261.49522	6.61	0.0473
Drying	1	1225.27722	1225.27722	0.24	0.7105
Expt*drying	1	5127.32838	5127.32838	-13.26	.
Expt*rep*drying	4	1369.41705	342.35426	0.57	0.6854
Blanching	2	679.86133	339.93067	0.66	0.6020
Expt*blanch	2	1028.18317	514.09158	1.46	0.7714
Drying*blanch	2	637.70680	318.85340	0.73	0.5790
Expt*dry*blanch	2	876.91174	438.45587	0.32	0.7366
Chemical	3	49543.60364	16514.53455	33.65	0.0082
Expt*chemical	3	1472.18949	490.72983	0.69	0.7228
Drying*chemical	3	4829.17358	1609.72453	2.02	0.2898
Expt*dry*chemical	3	2396.53514	798.84505	0.59	0.6457
Blanch*chemical	6	6054.41330	1009.06888	0.79	0.6087
Expt*blanch*chemical	6	7658.27100	1276.37850	0.94	0.5304
Drying*blanch*chemical	6	7655.63192	1275.93865	0.94	0.5306
Expt*drying*blanc*chemical	6	8172.77969	1362.12995	2.27	0.0442
Error	88	52891.4125	601.0388		
Corrected total	143	162964.1229			

Table A15. Partial ANOVA for dried oyster mushroom Mn content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	104.0214887	104.0214887	12.00	0.0430
Rep (expt)	4	1.3403490	0.3350873	1.57	0.3360
Drying	1	2.0043577	2.0043577	0.67	0.5637
Expt*drying	1	2.9986293	2.9986293	-1.08	.
Expt*rep*drying	4	0.8528531	0.2132133	0.21	0.9341
Blanching	2	33.7331215	16.8665607	3.12	0.2430
Expt*blanch	2	10.8280460	5.4140230	-33.92	.
Drying*blanch	2	0.4803100	0.2401550	1.02	0.4960
Expt*drying*blanch	2	0.4727648	0.2363824	0.09	0.9178
Chemical	3	20.8741488	6.9580496	13.89	0.0289
Expt*chemical	3	1.5028761	0.5009587	3.84	0.9747
Drying*chemical	3	0.8411370	0.2803790	0.53	0.6910
Expt*drying*chemical	3	1.5788292	0.5262764	0.19	0.8970
Blanching*chemical	6	17.0445625	2.8407604	1.22	0.4062
Expt*blanch*chemical	6	13.9241758	2.3206960	0.85	0.5734
Drying*blanch*chemical	6	15.5741229	2.5956872	0.96	0.5213
Expt*drying*blanc*chemical	6	16.3000613	2.7166769	2.63	0.0214
Error	88	90.7674571	1.0314484		
Corrected total	143	336.0259609			

Table A16. Partial ANOVA for dried oyster mushroom Cu content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	1208.358754	1208.358754	0.92	0.4737
Rep (expt)	4	521.228701	130.307175	1.62	0.3265
Drying	1	1897.089994	1897.089994	1.72	0.4152
Expt*drying	1	1106.048118	1106.048118	-17.01	.
Expt*rep*drying	4	322.408087	80.602022	1.66	0.1670
Blanch	2	45.509552	22.754776	3.92	0.2034
Expt*blanch	2	11.617354	5.808677	-0.10	.
Drying*blanch	2	10.025426	5.012713	0.66	0.6030
Expt*drying*blanch	2	15.230038	7.615019	0.06	0.9390
Chemical	3	625.526106	208.508702	1.88	0.3087
Expt*chemical	3	332.859372	110.953124	-2.12	.
Drying*chemical	3	245.642037	81.880679	5.55	0.0966
Expt*dry*chemical	3	44.292785	14.764262	0.12	0.9430
Blanching*chemical	6	357.666992	59.611165	1.13	0.4420
Expt*blanch*chemical	6	315.918905	52.653151	0.44	0.8298
Drying*blanch*chemical	6	271.215950	45.202658	0.38	0.8696
Expt*drying*blanc*chemi	6	718.808722	119.801454	2.46	0.0300
Error	88	4278.99510	48.62494		
Corrected total	143	12178.61991			

Table A17. Partial ANOVA for dried oyster mushroom Fe content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	15078.72789	15078.72789	57.87	0.6432
Rep (expt)	4	306.25399	76.56350	0.77	0.5981
Drying	1	1.11103	1.11103	0.00	0.9674
Expt*dry	1	421.85805	421.85805	-20.61	.
Expt*rep*dry	4	399.06786	99.76696	0.51	0.7259
Blanch	2	3568.59644	1784.29822	3.37	0.2288
Expt*blanch	2	1058.92002	529.46001	0.59	0.5949
Drying*blanch	2	554.46678	277.23339	2.58	0.2793
Expt*dry*blanch	2	214.86983	107.43492	0.55	0.5771
Chemical	3	2598.58687	866.19562	2.06	0.2839
Expt*chemical	3	1261.12630	420.37543	0.43	0.7413
Drying*chemical	3	483.69773	161.23258	0.88	0.5401
Expt*dry*chemical	3	548.74756	182.91585	0.85	0.5152
Blanching*chemical	6	2187.96387	364.66065	0.36	0.8803
Expt*blanch*chemical	6	6074.81160	1012.46860	4.71	0.0407
Drying*blanch*chemical	6	1506.77149	251.12858	1.17	0.4280
Expt*drying*blanch*chemical	6	1290.92899	215.15483	1.11	0.3644
Error	88	17093.19400	194.24084		
Corrected total	143	54653.04319			

Table A18. Partial ANOVA for dried oyster mushroom crude protein content.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	1777.120891	1777.120891	3.66	0.3951
Rep(Expt)	4	1399.252812	349.813203	1.26	0.4140
Drying	1	437.328662	437.328662	1.12	0.4816
Expt*drying	1	389.612376	389.612376	1.58	0.5219
Expt*rep*drying	4	1110.271896	277.567974	0.92	0.4551
Blanch	2	581.952281	290.976141	1.18	0.4589
Expt*blanch	2	493.472352	246.736176	1.04	0.5925
Drying*blanch	2	569.877979	284.938989	1.01	0.4971
Expt*drying*blanch	2	563.215494	281.607747	0.92	0.4493
Chemical	3	817.635221	272.545074	0.88	0.5389
Expt*chemical	3	924.026031	308.008677	1.23	0.5517
Drying*chemical	3	1069.426684	356.475561	1.20	0.4413
Expt*drying*chemical	3	888.587877	296.195959	0.96	0.4683
Blanch*chemical	6	1503.312425	250.552071	0.96	0.5205
Expt*blanch*chemical	6	1570.389884	261.731647	0.85	0.5745
Drying*blanch*chemical	6	1738.762527	289.793755	0.94	0.5272
Expt*drying*blanch*chemi	6	1842.616606	307.102768	1.02	0.4178
Error	88	26498.96295	301.12458		
Corrected Total	143	44192.59535			

Table A19. Partial ANOVA for dried oyster mushroom mold infestation.

Source	DF	Sum of squares	Mean square	F value	Pr > F
Drying	1	1.156612	1.156612	7.20	0.2276
Blanch	2	1.642185	0.821093	4.05	0.1980
Drying*blanch	2	0.227461	0.113731	4.80	0.1724
Chemical	3	21.010197	7.003399	27.13	0.0113
Drying*chemical	3	0.802630	0.267543	1.93	0.3009
Blanch*chemical	6	6.512388	1.085398	6.70	0.0179
Drying*blanch*chemical	6	0.443010	0.073835	0.60	0.7255
Experiment	1	0.048863	0.048863	0.10	0.7714
Rep (expt)	9	1.560596	0.173400	1.36	0.3271
Expt*drying	1	0.160575	0.160575	5.70	0.8153
Expt*rep*drying	9	1.147353	0.127484	0.92	0.5060
Expt*blanch	2	0.405465	0.202732	3.24	0.4988
Expt*drying*blanch	2	0.047388	0.023694	0.19	0.8300
Expt*chemical	3	0.774568	0.258189	1.46	0.4105
Expt*drying*chemical	3	0.415183	0.138394	1.12	0.4115
Expt*blanch*chemical	6	0.972705	0.162117	1.32	0.3740
Expt*drying*blanc*chemical	6	0.739682	0.123280	0.89	0.5012
Residual	198	27.342790	0.138095	.	.

Table A20. Partial ANOVA for dried oyster mushroom yellow color rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	2410.010417	2410.010417	0.78	0.3966
Rep (expt)	10	30729	3072.860417	4.86	<.0001
Chemical	3	9713.364583	3237.788194	5.12	0.0028
Drying	1	3737.510417	3737.510417	5.91	0.0174
Chemical*drying	3	8923.281250	2974.427083	4.70	0.0046
Error: MS(error)	77	48712	632.622971		
Corrected total	95	104224.7396			

Table A21. Partial ANOVA for dried oyster mushroom brown color rating.

Source of variation	DF	Type III SS	Mean square	F Value	Pr > F
Experiment	1	137.760417	137.760417	0.24	0.6319
Rep (experiment)	10	5644.104167	564.410417	1.28	0.2593
Chemical	3	70621	23540	53.19	<.0001
Drying	1	7089.843750	7089.843750	16.02	0.0001
Chemical*drying	3	12749	4249.621528	9.60	<.0001
Error: MS (error)	77	34077	442.552624		
Corrected total	95	130317.9896			

Table A22. Partial ANOVA for dried oyster mushroom wrinkle rating.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Expt	1	1296.97337	1296.97337	3.28	0.0741
Rep(expt)	10	18192.45088	1819.24509	4.60	<.0001
chemical	3	9182.83095	3060.94365	7.74	0.0001
Drying	1	109.39644	109.39644	0.28	0.6005
chemical*Drying	3	2350.14710	783.38237	1.98	0.1240
Error	76	30061.36905	395.54433		
Corrected Total	94	60882.35789			

Table A23. Partial ANOVA for dried oyster mushroom meaty flavor attribute rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	590.041667	590.041667	0.21	0.6555
Rep(expt)	10	27915	2791.520833	5.00	<.0001
Chemical	3	3793.083333	1264.361111	2.27	0.0875
Drying	1	0	0	0.00	1.0000
Chemical*drying	3	1378.083333	459.361111	0.82	0.4850
Error: MS (error)	77	42968	558.027056		
Corrected total	95	76644.50000			

Table A24. Partial ANOVA for dried oyster mushroom sour flavor rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	90.093750	90.093750	0.10	0.7558
Rep (expt)	10	8816.437500	881.643750	3.03	0.0028
Chemical	3	5081.114583	1693.704861	5.83	0.0012
Drying	1	119.260417	119.260417	0.41	0.5237
Chemical*drying	3	538.114583	179.371528	0.62	0.6061
Error: MS (error)	77	22384	290.706304		
Corrected total	95	37029.40625			

Table A25. Partial ANOVA for dried oyster mushroom soapy flavor rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	55.510417	55.510417	0.04	0.8402
Rep (expt)	10	12955	1295.510417	10.55	<.0001
Chemical	3	2275.281250	758.427083	6.18	0.0008
Drying	1	52.510417	52.510417	0.43	0.5150
Chemical*drying	3	116.864583	38.954861	0.32	0.8128
Error: MS (error)	77	9452.468750	122.759334		
Corrected total	95	24907.73958			

Table A26. Partial ANOVA for dried oyster mushroom rubbery attribute rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	94.010417	94.010417	0.09	0.7735
Rep (expt)	10	10753	1075.310417	2.10	0.0345
Chemical	3	153.531250	51.177083	0.10	0.9599
Drying	1	688.010417	688.010417	1.34	0.2502
chemical*drying	3	3879.531250	1293.177083	2.52	0.0639
Error: MS (error)	77	39464	512.516910		
Corrected total	95	55031.98958			

Table A27. Partial ANOVA for dried oyster mushroom fibrous attribute rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Rep(expt)	10	19296	1929.645833	2.65	0.0078
Chemical	3	5570.375000	1856.791667	2.55	0.0616
Drying	1	477.041667	477.041667	0.66	0.4206
Chemical*drying	3	724.708333	241.569444	0.33	0.8022
Error: MS (error)	77	56020	727.537338		
Corrected total	95	85939.62500			

Table A28. Partial ANOVA for dried oyster mushroom overall acceptability rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	3504.166667	3504.166667	0.91	0.3619
Rep (expt)	10	38390	3838.991667	10.17	<.0001
Chemical	3	54007	18002	47.70	<.0001
Drying	1	145.041667	145.041667	0.38	0.5371
Chemical*drying	3	1068.375000	356.125000	0.94	0.4238
Error: MS (error)	77	29057	377.366883		
Corrected total	95	126171.3333			

Table A29. Partial ANOVA for dried oyster mushroom fibrous attribute rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	51.041667	51.041667	0.02	0.8792
Rep(expt)	10	20985	2098.466667	3.83	0.0003
Drying	1	222.041667	222.041667	0.41	0.5264
Blanching	1	3700.166667	3700.166667	6.75	0.0112
Drying*blanching	1	840.166667	840.166667	1.53	0.2195
Chemical	1	247.041667	247.041667	0.45	0.5040
Drying*chemical	1	247.041667	247.041667	0.45	0.5040
Blanching*chemical	1	912.666667	912.666667	1.66	0.2008
Drying*blanch*chemic	1	7776.000000	7776.000000	14.18	0.0003
Error: MS (error)	77	42212	548.209416		
Corrected total	95	77192.95833			

Table A30. Partial ANOVA for dried oyster mushroom rubbery attribute rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	88.166667	88.166667	0.03	0.8672
Rep (expt)	10	29934	2993.366667	4.80	<.0001
Drying	1	266.666667	266.666667	0.43	0.5152
Blanching	1	840.166667	840.166667	1.35	0.2494
drying*blanching	1	160.166667	160.166667	0.26	0.6138
Chemical	1	170.666667	170.666667	0.27	0.6025
drying*chemical	1	5400.000000	5400.000000	8.66	0.0043
blanching*chemical	1	0.666667	0.666667	0.00	0.9740
drying*blanch*chemic	1	352.666667	352.666667	0.57	0.4544
Error: MS (error)	77	48039	623.876623		
Corrected total	95	85251.33333			

Table A31. Partial ANOVA for dried oyster mushroom brown color rating.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Experiment	1	3.760417	3.760417	0.00	0.9495
Rep (expt)	10	8929.604167	892.960417	1.67	0.1041
Drying	1	283.593750	283.593750	0.53	0.4691
Blanching	1	20388	20388	38.05	<.0001
Drying*blanching	1	19.260417	19.260417	0.04	0.8501
Chemical	1	17361	17361	32.40	<.0001
Drying*chemical	1	3687.760417	3687.760417	6.88	0.0105
Blanching*chemical	1	1086.760417	1086.760417	2.03	0.1584
Drying*blanch*chemic	1	1560.093750	1560.093750	2.91	0.0920
Error: MS (error)	77	41258	535.823187		
Corrected total	95	94577.98958			

Table A32. Partial ANOVA for dried oyster mushroom yellow color rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	925.041667	925.041667	0.77	0.4003
Rep (expt)	10	11985	1198.483333	4.84	<.0001
Drying	1	400.166667	400.166667	1.62	0.2073
Blanching	1	852.041667	852.041667	3.44	0.0673
Drying*blanching	1	37.500000	37.500000	0.15	0.6981
Chemical	1	126.041667	126.041667	0.51	0.4775
Drying*chemical	1	912.666667	912.666667	3.69	0.0585
Blanching*chemical	1	145.041667	145.041667	0.59	0.4462
Drying*blanch*chemic	1	204.166667	204.166667	0.83	0.3665
Error: MS(error)	77	19049	247.391234		
Corrected total	95	34636.62500			

Table A33. Partial ANOVA for dried oyster mushroom wrinkle attribute rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	748.166667	748.166667	0.90	0.3643
Rep(expt)	10	8283.208333	828.320833	3.97	0.0002
Drying	1	433.500000	433.500000	2.08	0.1535
Blanching	1	216.000000	216.000000	1.04	0.3121
Drying*blanching	1	247.041667	247.041667	1.18	0.2799
Chemical	1	864.000000	864.000000	4.14	0.0453
Drying*chemical	1	77.041667	77.041667	0.37	0.5452
Blanching*chemical	1	176.041667	176.041667	0.84	0.3612
Drying*blanch*chemic	1	504.166667	504.166667	2.42	0.1241
Error: MS (error)	77	16062	208.603355		
Corrected total	95	27611.62500			

Table A34. Partial ANOVA for dried oyster mushroom sour attribute rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	1066.666667	1066.666667	1.49	0.2497
Rep (expt)	10	7142.791667	714.279167	3.78	0.0004
Drying	1	0.666667	0.666667	0.00	0.9528
Blanching	1	900.375000	900.375000	4.76	0.0321
Drying*blanching	1	240.666667	240.666667	1.27	0.2626
Chemical	1	2773.500000	2773.500000	14.67	0.0003
Drying*chemical	1	360.375000	360.375000	1.91	0.1713
Blanching*chemical	1	150.000000	150.000000	0.79	0.3758
Drying*blanch*chemic	1	26.041667	26.041667	0.14	0.7115
Error: MS (error)	77	14553	188.998377		
Corrected total	95	27213.95833			

Table A35. Partial ANOVA for dried oyster mushroom meaty attribute rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	0.843750	0.843750	0.00	0.9894
Rep (expt)	10	45179	4517.918750	18.15	<.0001
Drying	1	86.260417	86.260417	0.35	0.5578
Blanching	1	446.343750	446.343750	1.79	0.1844
Drying*blanching	1	128.343750	128.343750	0.52	0.4748
Chemical	1	283.593750	283.593750	1.14	0.2891
Crying*chemical	1	49.593750	49.593750	0.20	0.6565
Blanching*chemical	1	243.843750	243.843750	0.98	0.3253
Drying*blanch*chemic	1	195.510417	195.510417	0.79	0.3782
Error: MS (error)	77	19162	248.855655		
Corrected total	95	65775.40625			

Table A36. Partial ANOVA for dried oyster mushroom soapy attribute rating.

Source	DF	Type III SS	Mean square	F value	Pr > F
Experiment	1	110.510417	110.510417	0.03	0.8629
Rep (expt)	10	35184	3518.435417	31.70	<.0001
Drying	1	3.760417	3.760417	0.03	0.8544
Blanching	1	142.593750	142.593750	1.28	0.2605
Drying*blanching	1	106.260417	106.260417	0.96	0.3309
Chemical	1	263.343750	263.343750	2.37	0.1276
Drying*chemical	1	0.510417	0.510417	0.00	0.9461
Blanching*chemical	1	38.760417	38.760417	0.35	0.5563
Drying*blanch*chemic	1	1.760417	1.760417	0.02	0.9001
Error: MS (error)	77	8546.385417	110.992018		
Corrected total	95	44398.23958			

Table A37. Partial ANOVA for dried oyster mushroom overall acceptability rating.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Expt	1	4428.166667	4428.166667	0.97	0.3485
Rep(expt)	10	45771	4577.129167	13.30	<.0001
Drying	1	1700.166667	1700.166667	4.94	0.0292
Blanching	1	8066.666667	8066.666667	23.44	<.0001
drying*blanching	1	672.041667	672.041667	1.95	0.1663
Chemical	1	9963.375000	9963.375000	28.95	<.0001
drying*chemical	1	2053.500000	2053.500000	5.97	0.0169
blanching*chemical	1	0.666667	0.666667	0.00	0.9650
drying*blanch*chemic	1	532.041667	532.041667	1.55	0.2175
Error: MS(Error)	77	26498	344.130411		
Corrected Total	95	99685.95833			

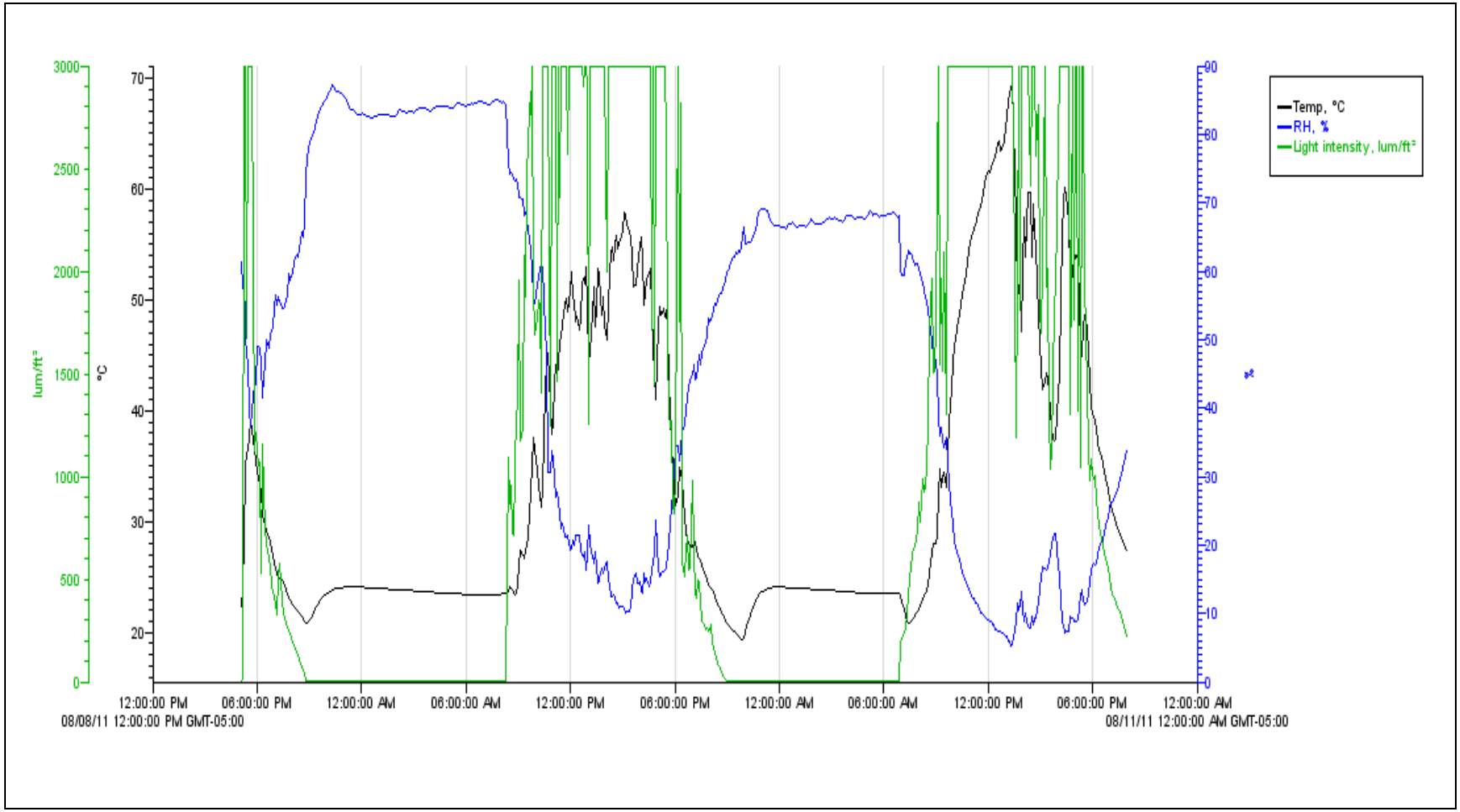


Figure A1. Drying conditions in solar drier #1 used for oyster mushroom drying, 08/08/2011-08/10/2011.

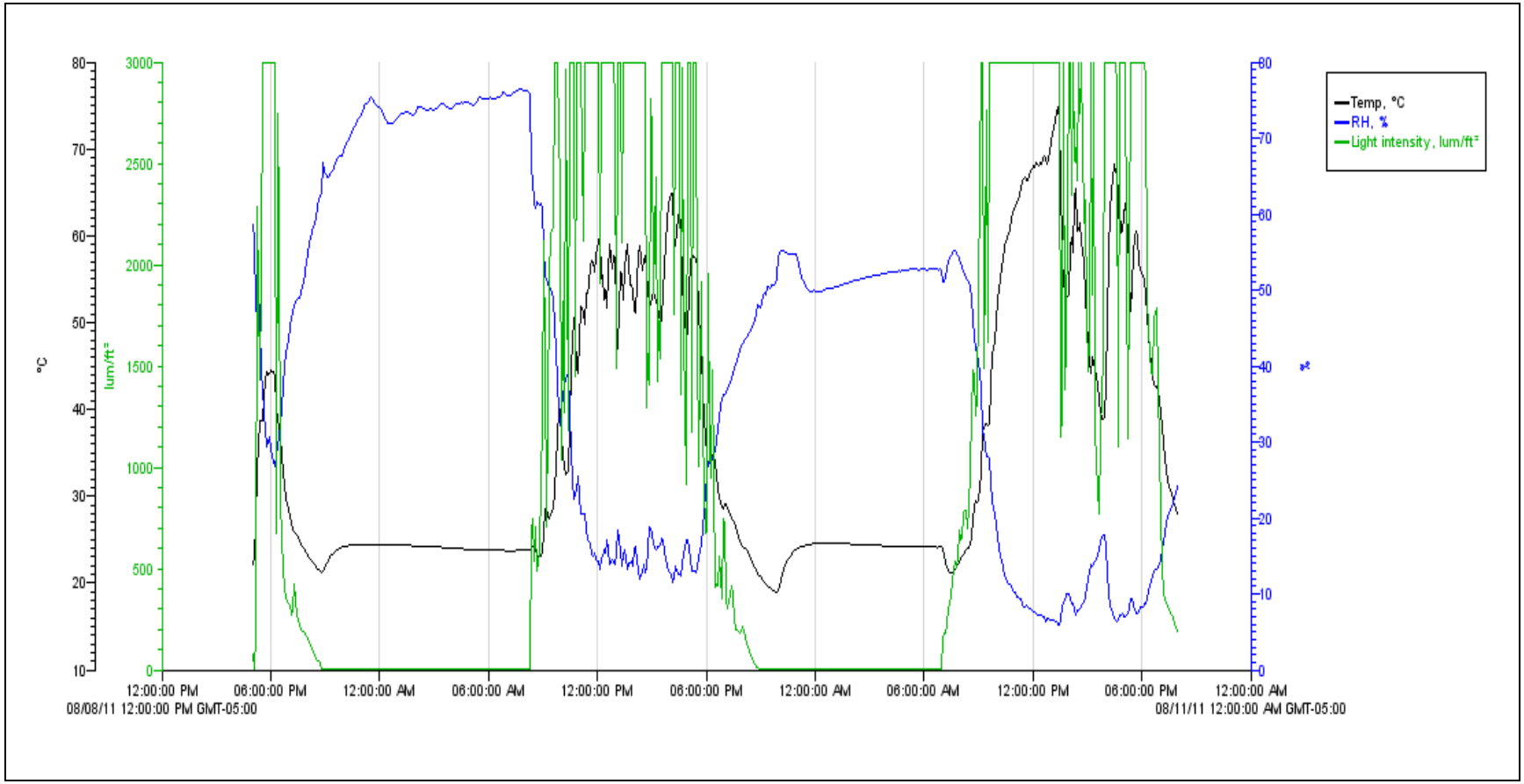


Figure A2. Drying conditions in solar drier #2 used for oyster mushroom drying, 08/08/2011-08/10/2011.

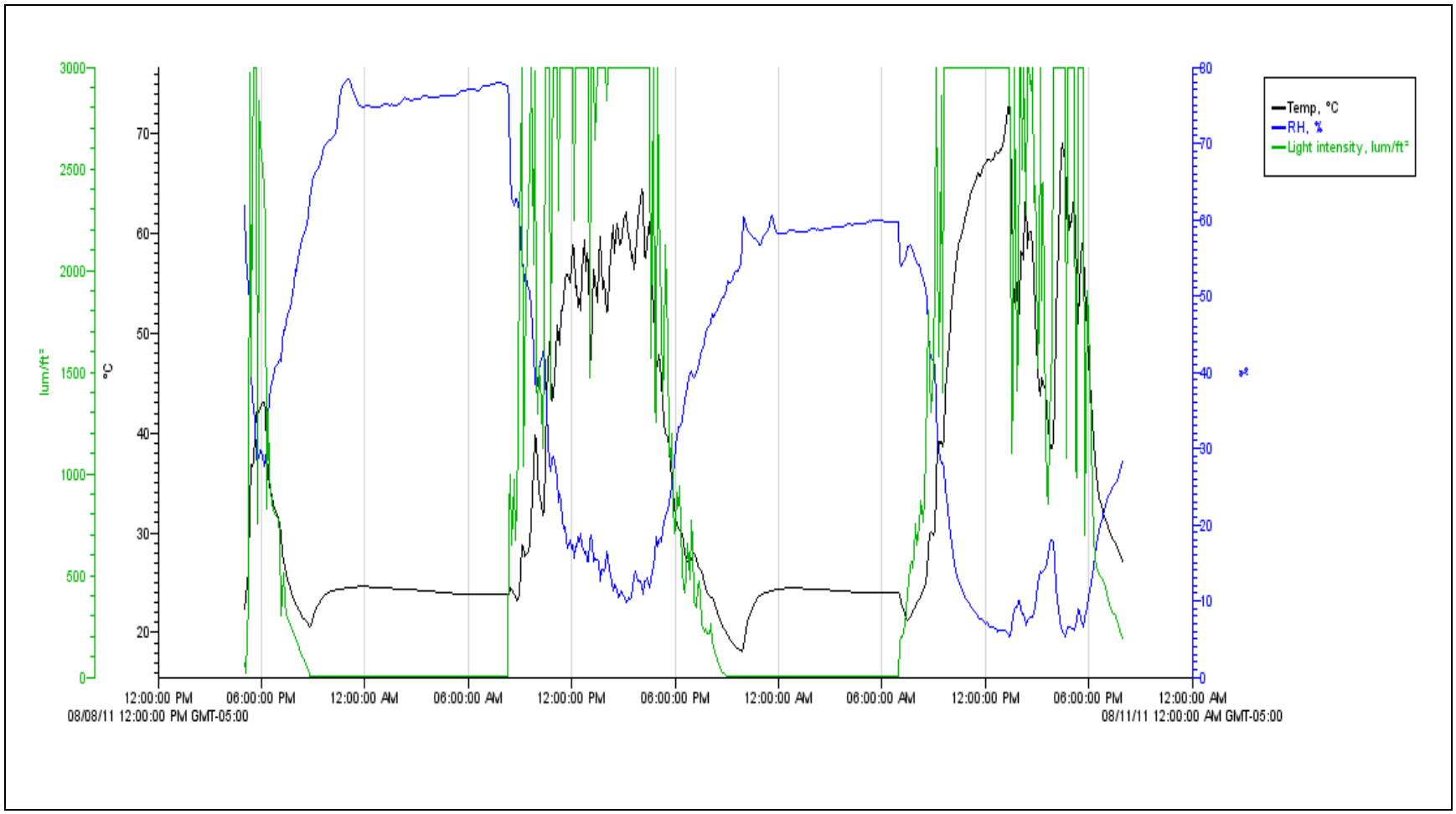


Figure A3. Drying conditions in solar drier #3 used for oyster mushroom drying, 08/08/2011-08/10/2011.

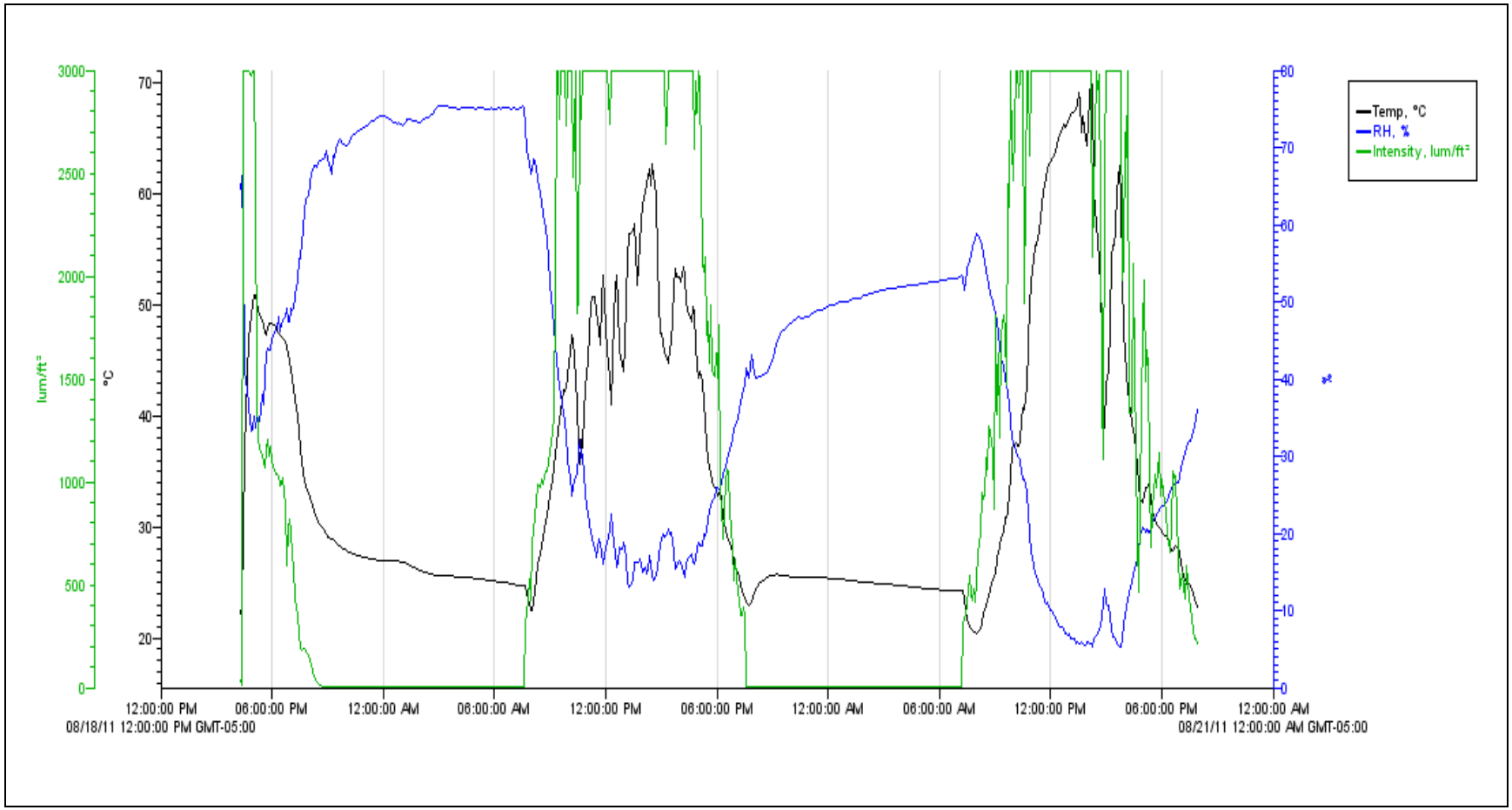


Figure A4. Drying conditions in solar drier #2 used for oyster mushroom drying, 08/18/2011-08/20/2011.

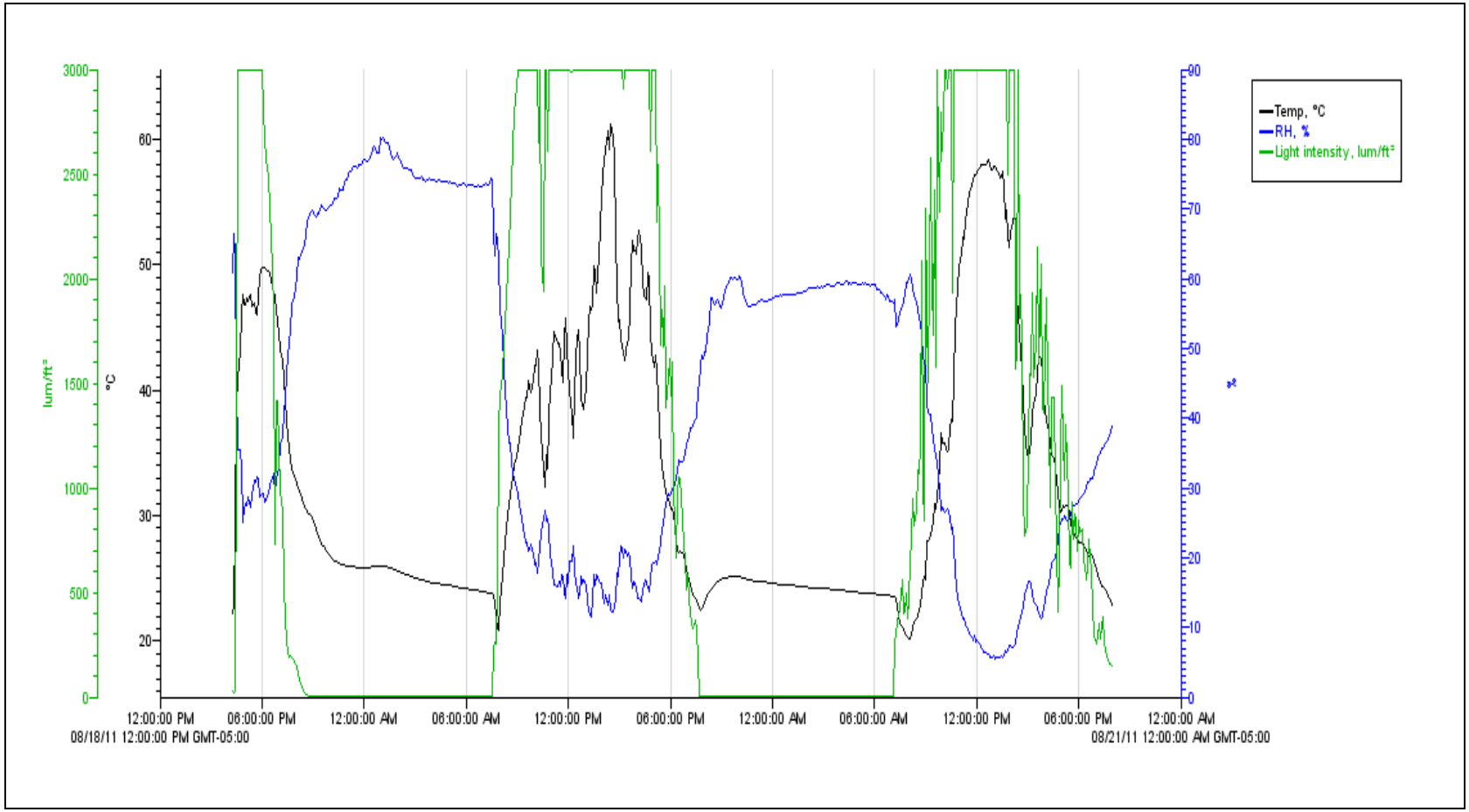


Figure A5. Drying conditions in solar drier #3 used for oyster mushroom drying, 08/18/2011-08/20/2011.

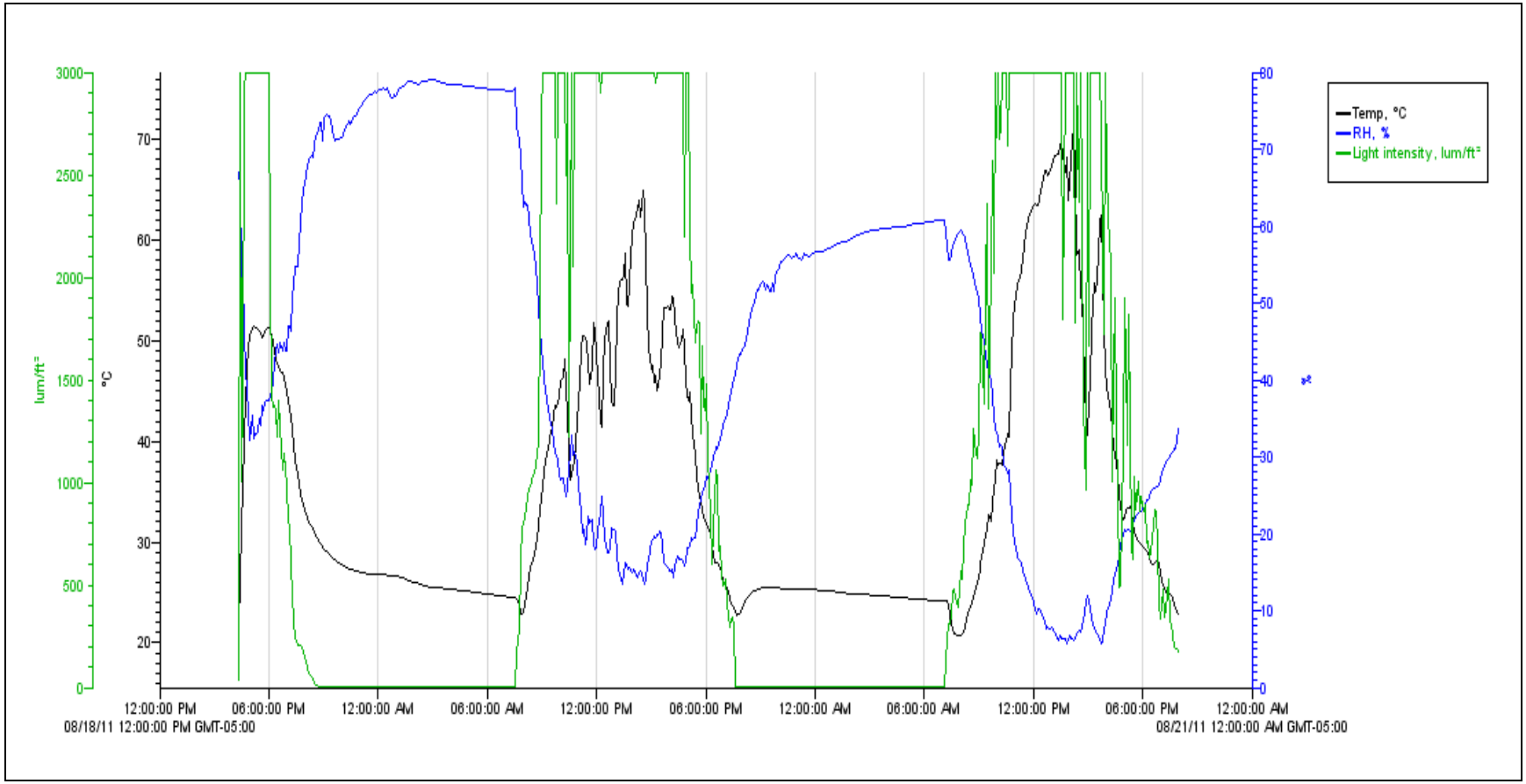


Figure A6. Drying conditions in solar drier #1 used for oyster mushroom drying, 08/18/2011-08/20/2011.

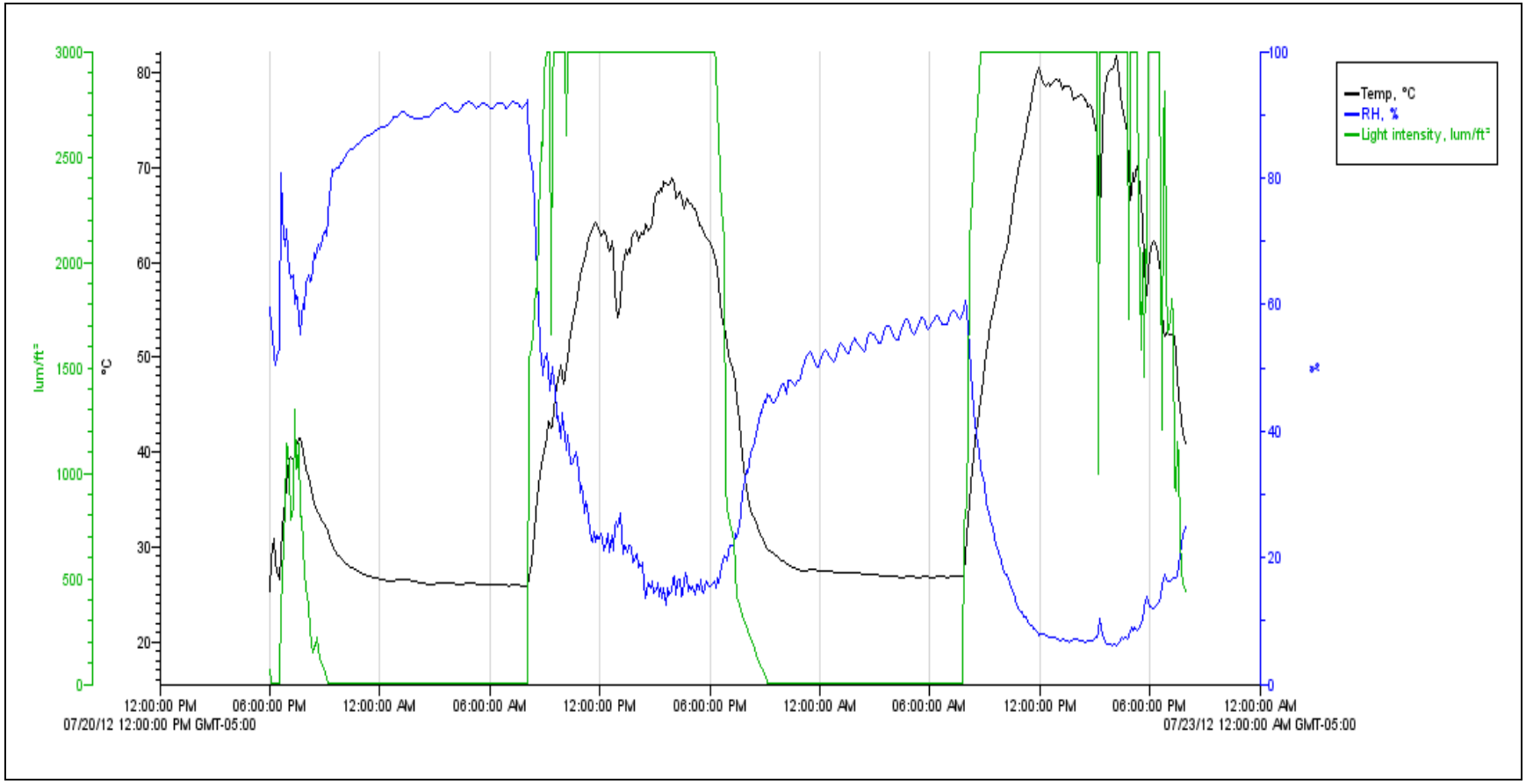


Figure A7. Drying conditions in solar drier #2 used for oyster mushroom drying, 07/20/2011-07/23/2012.

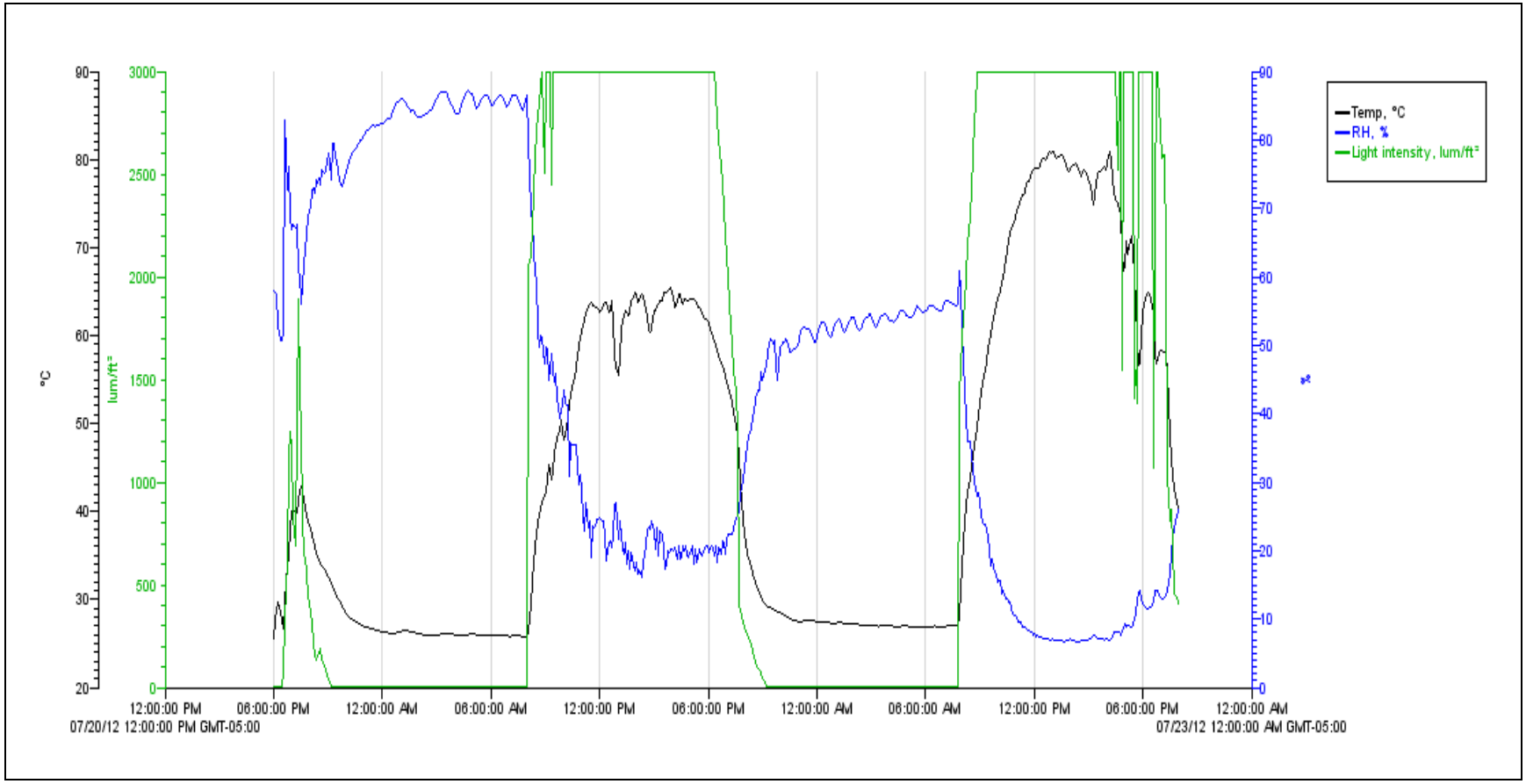


Figure A8. Drying conditions in solar drier #3 used for oyster mushroom drying, 07/20/2011-07/23/2012.

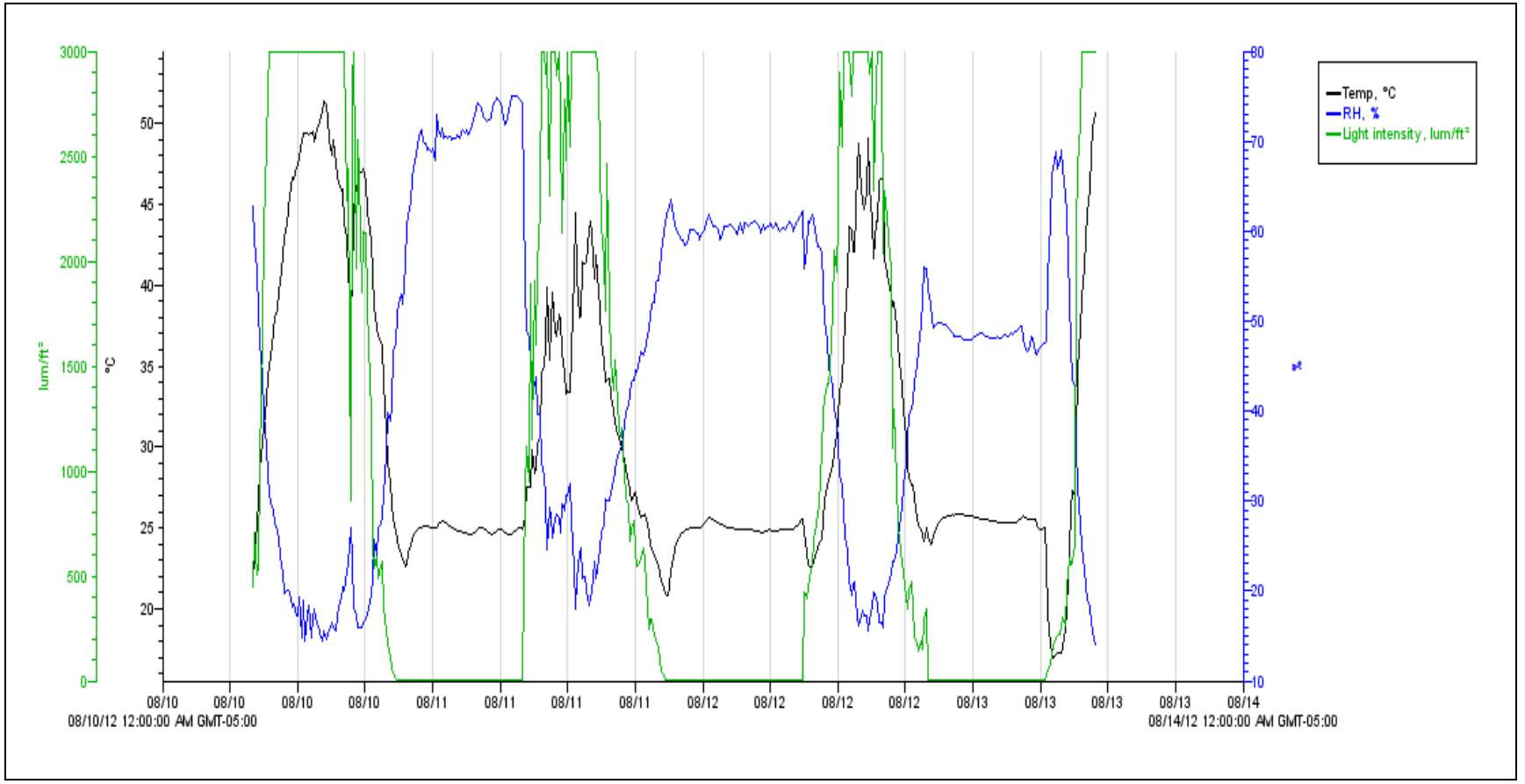


Figure A9. Drying conditions in solar drier #2 used for oyster mushroom drying, 08/10/2012- 08/13/2012.

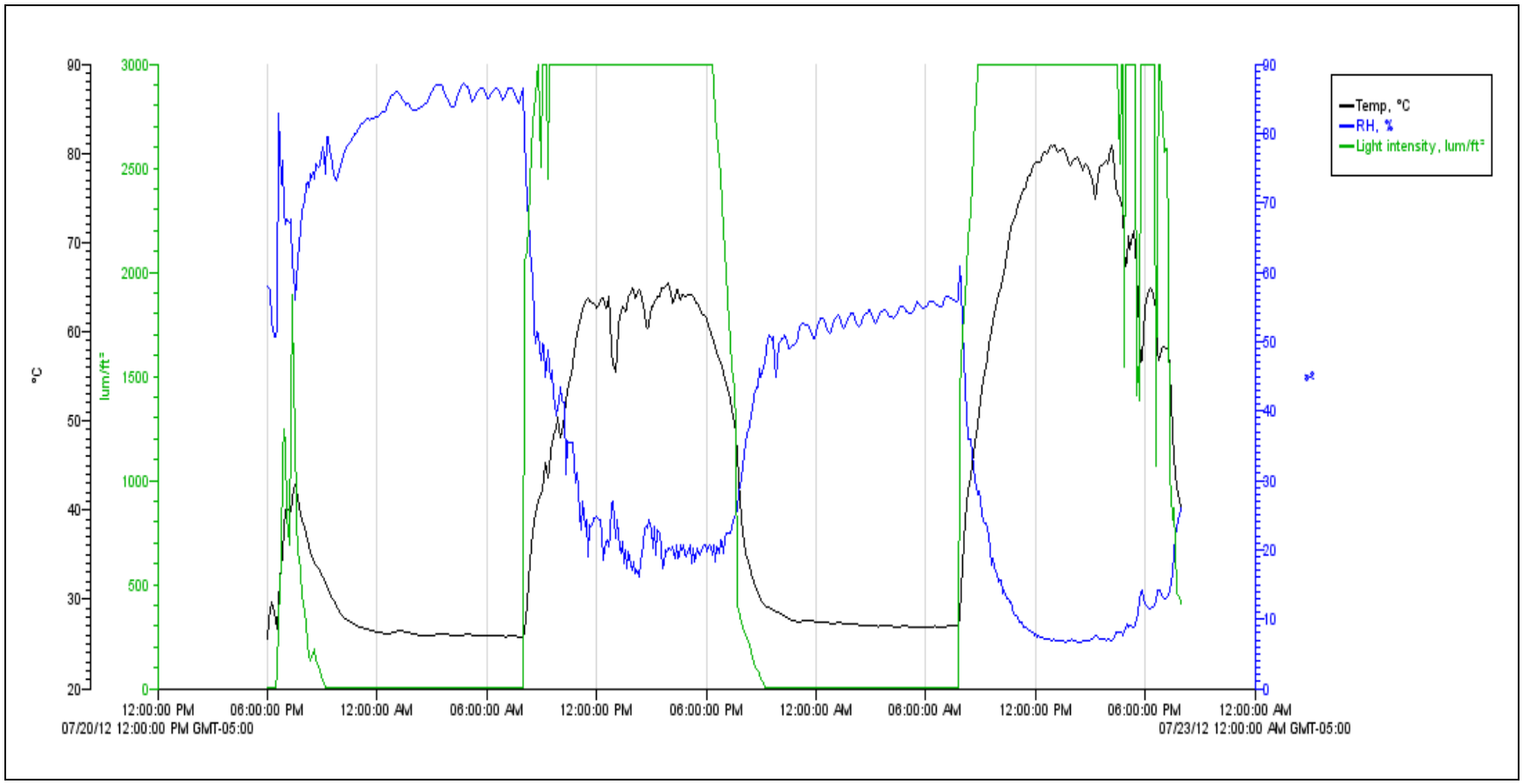


Figure A10. Drying conditions in solar drier #3 used for oyster mushroom drying, 08/10/2012- 08/13/2012.

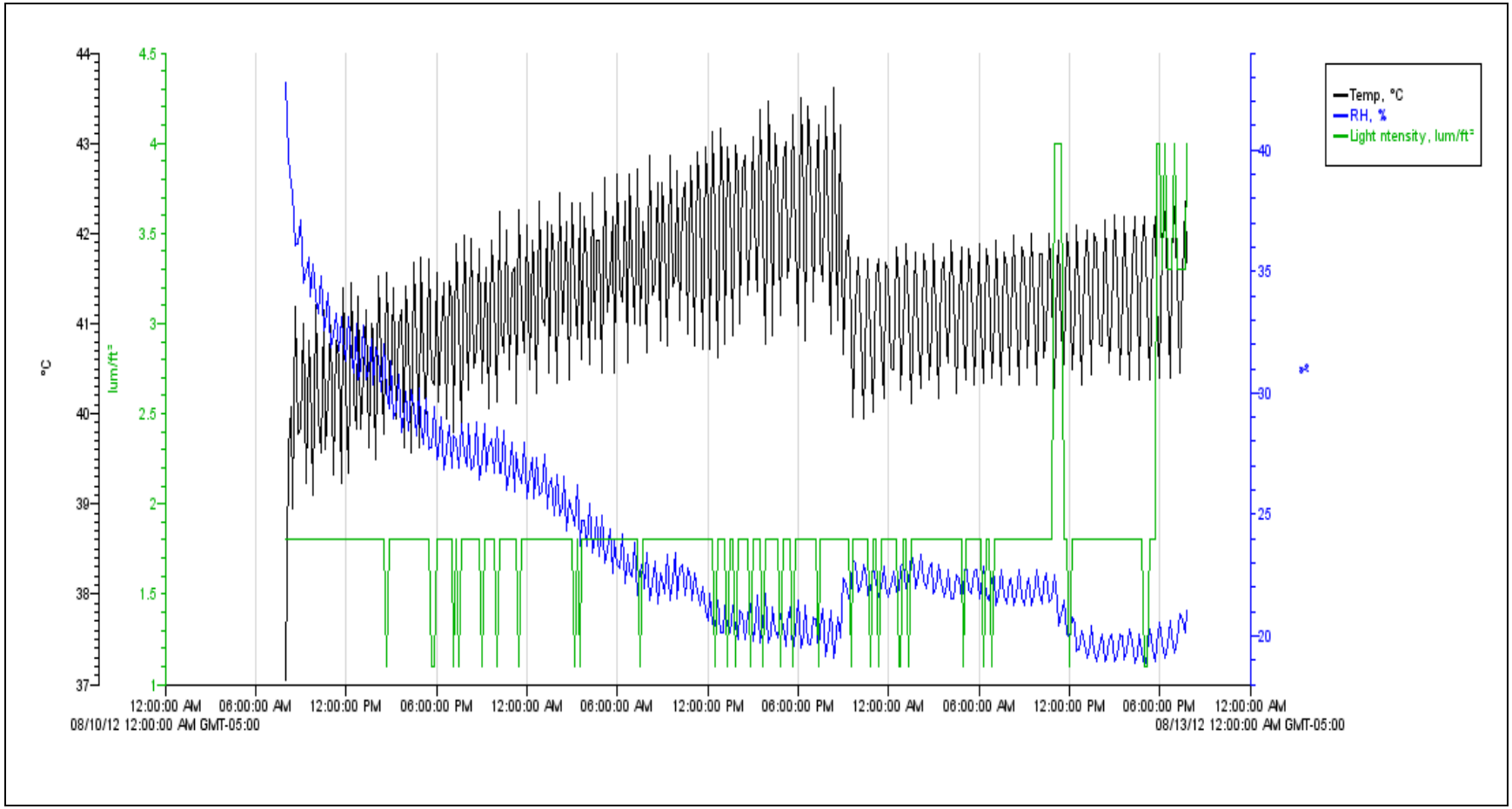


Figure A11. Drying conditions in oven drier used for oyster mushroom drying, 08/10/2012- 08/13/2012.

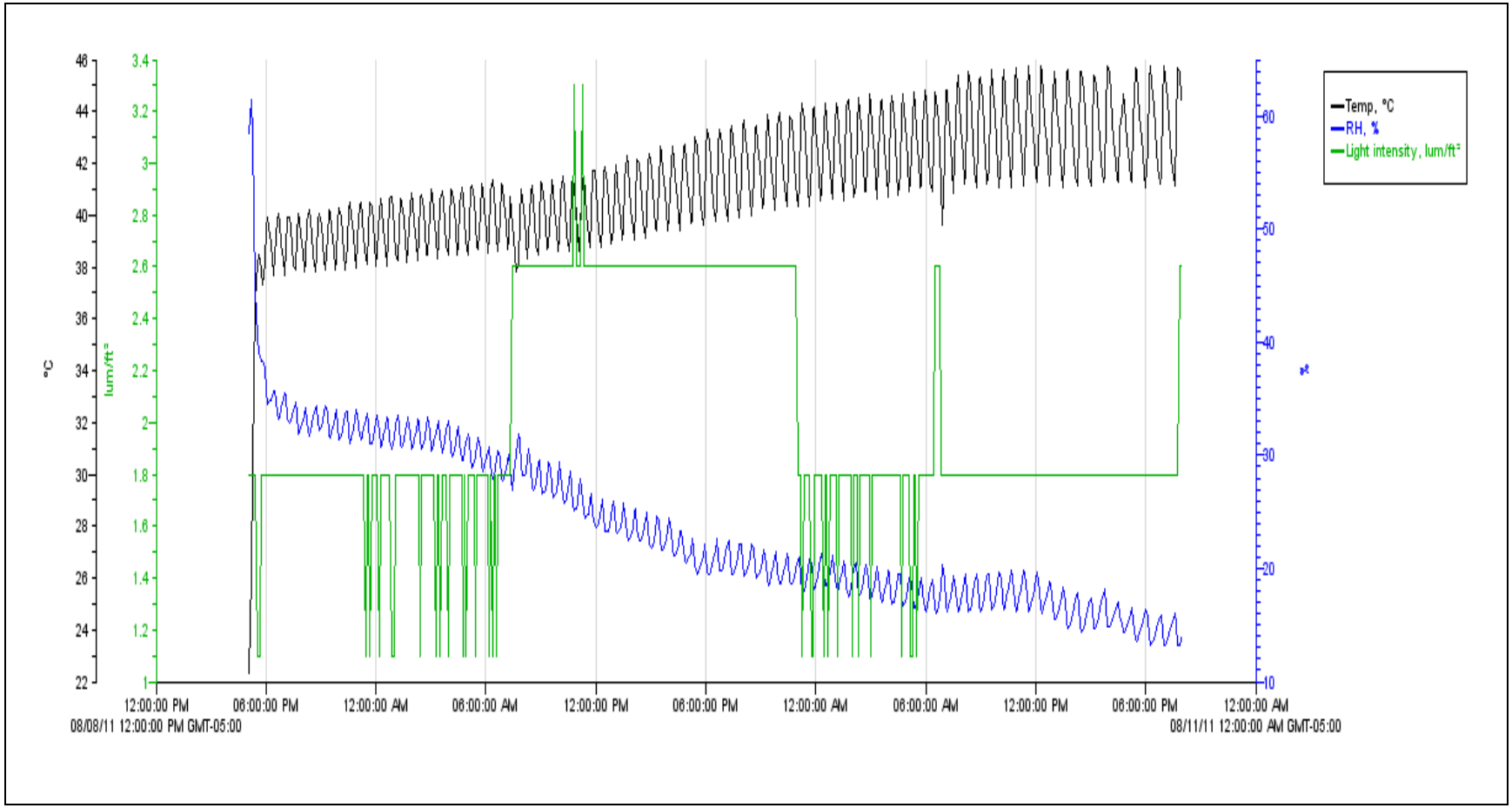


Figure A12. Drying conditions in oven drier used for oyster mushroom drying, 08/08/2011-08/10/2011.

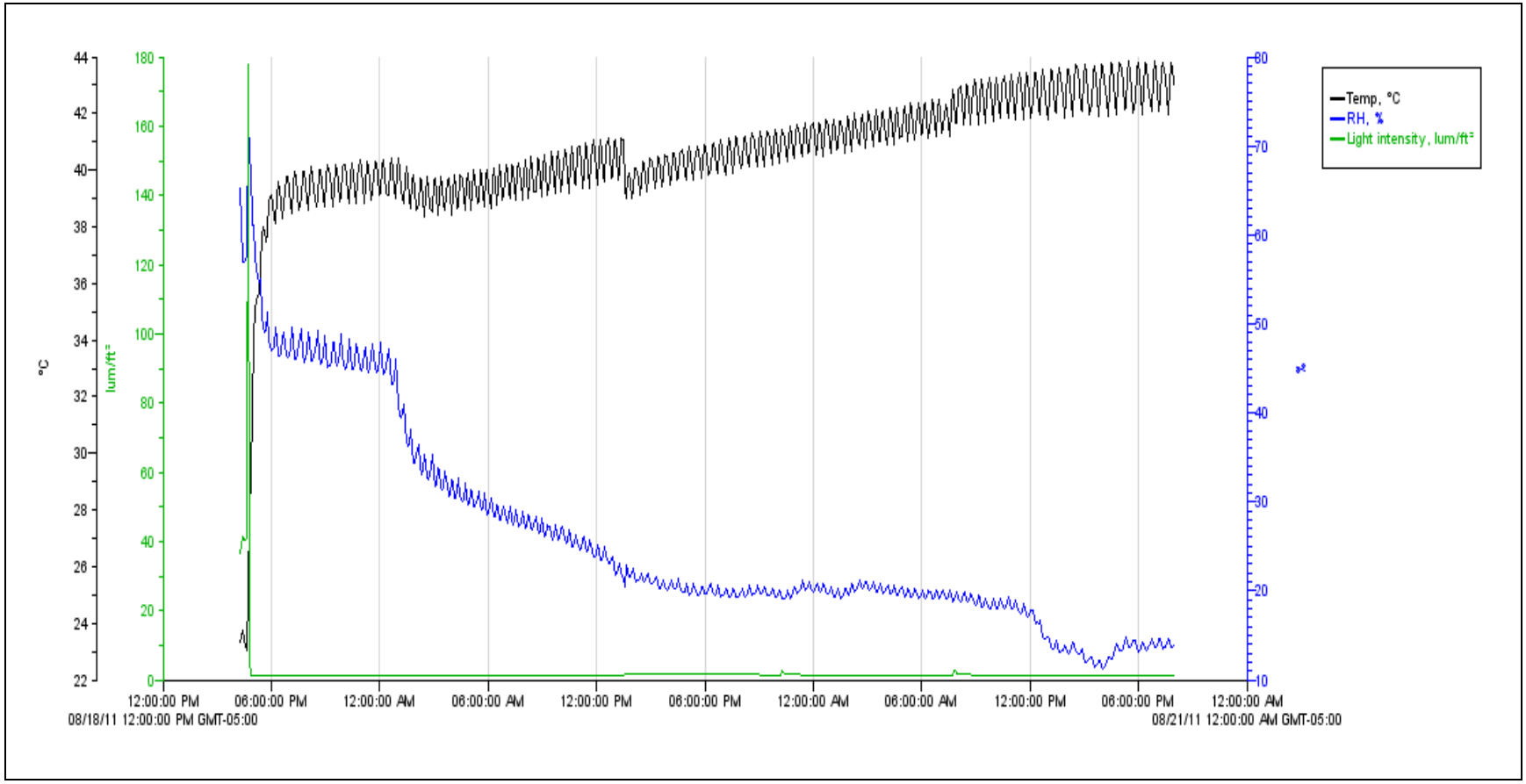


Figure A13. Drying conditions in oven drier used for oyster mushroom drying, 08/18/2011-08/20/2011.

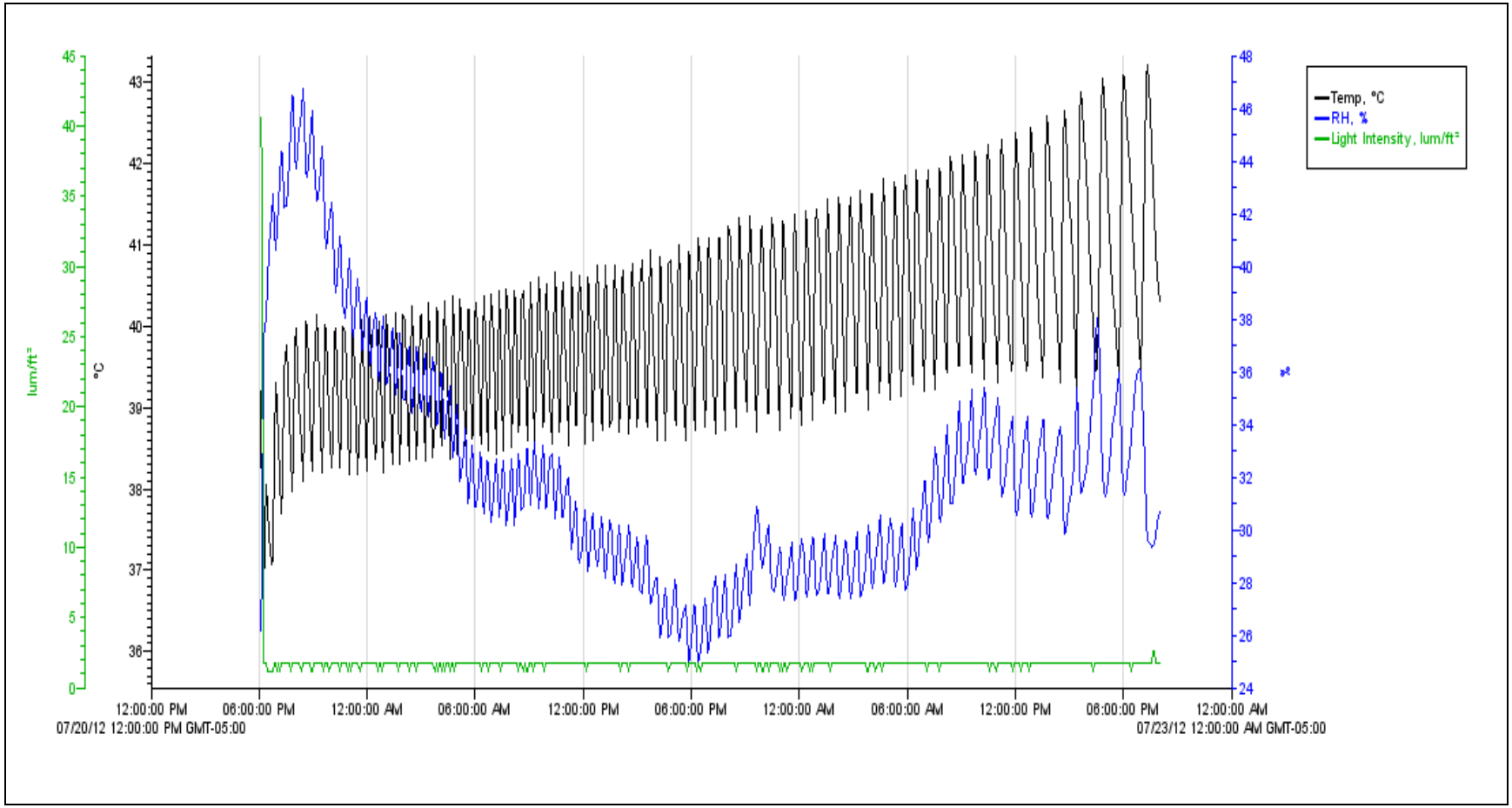


Figure A14. Drying conditions in oven drier used for oyster mushroom drying, 07/20/2011-07/23/2012.

Figure A15. Solar drier #1 used for oyster mushroom drrying, summer 2011.

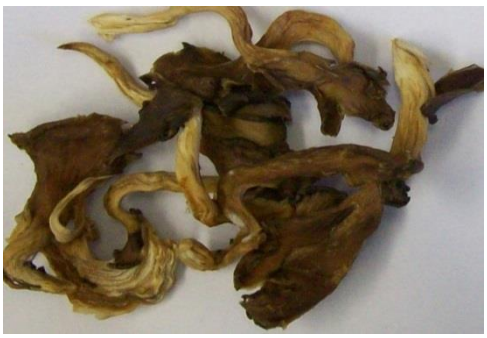
Figure A16. Solar driers #2 and #3 used for oyster mushroom drying, summer 2011 and 2012.

Steam blanching + Potassium bisulfite + Oven drying

Steam blanching + Potassium bisulfite + Solar drying

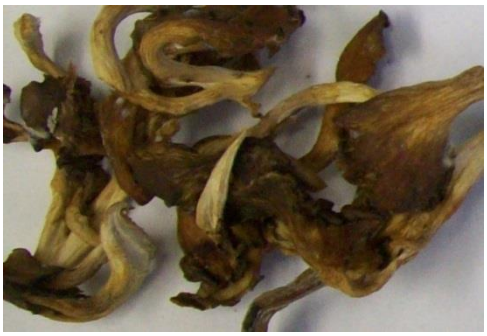
Water blanching + Potassium bisulfite + Oven drying

Water blanching + Potassium bisulfite + Solar drying

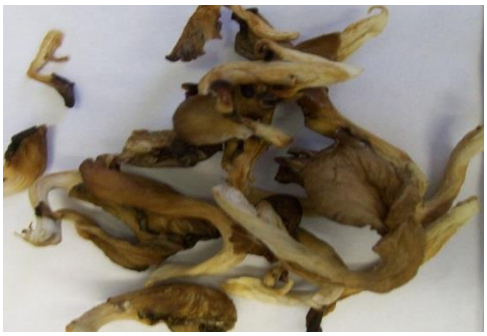


Water blanching + Vinegar + Oven drying

Water blanching + Vinegar + solar drying



Steam blanching + Vinegar + Oven drying



Water blanching + Vinegar + Oven drying

Figure A17. Mushroom samples for the second sensory analysis experiment.