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The Role of Mushrooms as a Functional Ingredient in Chocolate Chip Cookies

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Abstract: Mushrooms are becoming increasingly popular as a food ingredient in packaged foods. Current literature supports the use of mushrooms as a functional ingredient due to its nutrient density and association with potential health benefits. The purposes of this exploratory study were 1) to determine if the addition of white button mushrooms to a chocolate chip cookie formula would result in detectable differences from an identical recipe without mushrooms, and 2) to test the acceptance of white button mushrooms in a food product and gauge the likelihood of a consumer to purchase a food product that is fortified with edible mushrooms. Control and experimental nutrient-dense, chocolate chip cookie formulas were developed to conduct a sensory analysis evaluation using a triangle difference test: while both formulas were high in dietary protein and fiber, the experimental formula incorporated raw white button mushrooms in the unbaked dough (5.83% of the total composition). The results of the triangle test indicate that the addition of mushrooms did not result in meaningful sensory differences between formulations. Additionally, reported preference for mushrooms was not significantly related to correct determination of the different sample in the triangle test. This study also revealed that frequent consumption of protein powder and/or high fiber foods were not significantly related to participant likelihood of purchasing protein and/or fiber-fortified items. However, the likelihood of purchasing mushroom-fortified foods was significantly related to reported preference for mushrooms. Future research exploring the incorporation of mushrooms into popular food items can benefit from the trials of this research study. To establish a more imperceptible product fortified with mushrooms, using a milled version seems to contribute less moisture and texture.

Keywords: Mushrooms, Functional, Ingredient, Cookie, Food, Science

1. Introduction

In January 2021, the Institute of Food Technologists predicted that mushrooms would be among the top food trends for the upcoming year [8]. Wild mushrooms have been used for centuries for both nutritional and medicinal purposes [2, 6]. Different varieties of mushrooms can add an array of nutritional elements to otherwise less nutrient dense foods, and with those additional nutrients come additional health benefits. Many species have been shown to help prevent liver disease, heart disease, blood clotting, and diabetes, and also display antibacterial and anti-inflammatory properties [14]. The high amounts of fiber, protein, carbohydrates, and a low amount of fat makes the use of mushrooms for fortification a perfect candidate to enhance the nutritional quality of food products [2]. With over 2,000 species of mushrooms ready to eat and 35 varieties in mainstream production, there are plenty of choices and opportunities for more product ideas as the popularity of mushrooms continues to grow [14].

There are two groups of mushrooms that can be used for fortification, known as edible and medicinal [2, 7]. The fruiting bodies of these mushrooms can be eaten fresh, or dried and converted into a powder; they can also be eaten alone or incorporated into recipes [2]. Some of the most widely used mushrooms are variations of Agaricus bisporus such as button, baby bella, or portabella, as well as black truffle, chanterelle, and shiitake [2, 15].

2. Composition of Wild Mushrooms

Wild mushrooms of all types contain very few calories and fat, but are excellent sources of carbohydrates, fiber, and protein [2]. Mushrooms also have a wide variety of vitamins and minerals that contribute to their nutrient density.

Vitamins such as vitamin A, vitamin B-3, and folate are abundant, as well as minerals like potassium and copper [2, 12, 16]. Beyond a select few vitamins and minerals, studies on the availability of various micronutrients are limited [4]. Mushrooms are also rich in phenolic compounds that act as antioxidants, reduce viral microbes, and lower cholesterol [2, 5]. Many varieties of mushrooms contain all nine essential amino acids, making it a good substitute for other sources of meat derived proteins [14].

2.1. Fiber Content

As more people become interested in the health benefits of fiber such as the prevention of cardiovascular disease, diabetes, and certain cancers, as well as improving weight management, more fiber fortified products have been released and the industry continues to expand [3]. As the industry for fiber fortification expands, the foods from which the fiber comes from broadens as well as how those foods are prepared, and industry professionals look for new and exciting resources [3]. Mushrooms can easily be dried and milled, similar to other popular fiber containing products on the market like cereals and legumes, making them an ideal alternative source for dietary fiber [3].

In comparison to other high-fiber foods, mushrooms contain chitin in their cell walls [3]. Chitin cannot be digested by the human body, making it a source of dietary fiber [3]. According to Cheung (2013), "consumption of edible mushrooms as part of our daily diet can easily provide up to 25% of the recommended dietary intake of DF" (p. 163). With most Americans reportedly grossly under-consuming fiber in their diet, eating mushrooms and the by-products of mushrooms is an excellent way to obtain high amounts of fiber to supplement any diet [13].

2.2. Vitamin Content

Several prominent vitamins present in mushrooms include riboflavin, niacin, and folate [2, 12]. Some species of mushrooms can have more vitamin content than that found in vegetables and dairy products, making mushrooms a perfect substitute for a modified diet or addition to a less wholesome diet [2]. Other notable vitamins include B vitamins such as pyridoxine and thiamine, as well as amounts of Vitamin D that are improved with treatment from ultraviolet radiation [9].

2.3. Mineral Content

Several major minerals in mushrooms include potassium, phosphorus, magnesium, zinc, copper, and selenium [2, 16]. Other notable minerals include calcium and iron [14].

2.4. Wild Mushrooms as Prebiotics

Mushrooms contain components such as chitin, hemicellulose, beta glucans, mannans, xylans, and galacans, which have all demonstrated prebiotic properties [9]. Prebiotics in foods help promote healthy bacterial growth in the gastrointestinal tract that protect the body from infections from dangerous pathogens and microbes, as well as prevent diseases like diabetes, obesity, and certain cancers [9].

Reishi (Ganoderma lingzhi) mushrooms have been used widely for many years for their anti-inflammatory, immune boosting, and mental health properties [9]. These types of mushrooms have been shown to promote growth of lactobacillus, roseburia, and lachnospiraaceae, which act as helpful bacteria in the gastrointestinal tract and can prevent pancreatitis [9]. With nearly 400 species of mushrooms containing pharmaceutical characteristics, we will subsequently see marketing for prebiotics supplied from mushrooms as interest and research allows for it [9].

3. Review of Literature

In a 2007 study, Kumar and Barmanray assessed health benefits of mushrooms in biscuits by substituting White Button (Agaricus bisporus) mushroom flour in a recipe with wheat flour. The purpose of the study was to evaluate the nutrient composition of biscuits after adding mushrooms in comparison to a control, as well as evaluate their various sensory characteristics. Biscuits with varying levels of added mushrooms were evaluated: 0%, 5%, 10%, 15%, and 20% [10].

Each biscuit was evaluated based on appearance, fragrance, texture, flavor, and overall likeability by a team of panelists using a nine-point hedonic scale, although the exact number of participants was not reported [10]. As increasing amounts of mushroom flour was added, overall desirability decreased. No changes in characteristics were detected up to 5% added mushrooms and any addition over 10% had decreased reports of likeability. The researchers concluded that no more than 10% mushrooms should be added to biscuit dough to obtain the most desirable biscuit overall [10].

A similar study conducted in 2012 by Mahamud, Shirshir, and Hasan addressed the health benefits of mushrooms in bread by substituting milled Oyster (Pleurotus ostreatus) mushroom flour in a recipe with wheat flour. The purpose of the study was to create a more nutritious version of wheat bread while still maintaining the likeable sensory characteristics of wheat bread without mushrooms. The researchers created four samples of bread with varying levels of added mushrooms: 0%, 5%, 10%, and 15%.

A panel of fifteen people participated in the sensory evaluation and scored each variation of bread on characteristics of appearance, taste, texture, and overall likeability [11]. Results indicated that no more than 10% mushrooms should be added to bread dough to maintain an overall desirable mushroom fortified bread [11].

In a 2019 study, researchers Biao et al. analyzed the health benefits of mushrooms in cookies by substituting milled King Trumpet (Pleurotus eryngii) mushroom flour in a recipe with wheat flour. The purpose of the study was to create a more nutrient dense version of a cookie while maintaining overall quality and likability [1]. The researchers created cookies with varying levels of added mushrooms: 0%, 5%, 10%, 15%, and 20% [1].

Twenty trained panelists participated in the sensory

evaluation of randomly coded cookies based on aroma, appearance, mouthfeel, texture, and flavor characteristics using a nine-point hedonic scale [1]. The results of the sensory evaluation in the Biao et al. (2019) study showed that mushroom flour of up to 15% were preferred, and more than 15% incorporation decreased the cookies texture and flavor characteristics. With increasing addition of mushrooms, the quality of the dough decreased due to the gluten in the dough becoming weaker, leading to a denser cookie [1]. The researchers concluded that no more than 15% mushrooms should be added to cookie dough to obtain the most desirable cookie overall [1].

Considering the previous research conducted in assessing nutrient density and sensory characteristics of mushrooms incorporated into baked goods, the overall deduction is that between 10-15% mushrooms added to a recipe will give wanted health benefits while still maintaining acceptable standards of likeability similar to the control. Evaluating mushroom fortified products using discriminatory testing will add to the existing literature, which is primarily composed of affective testing methodologies.

4. Study Purpose

The purpose of this research study was to determine whether the addition of mushrooms to a nutrient-dense chocolate chip cookie formula would be detectable from a similar formula without mushrooms. The research questions and accompanying hypotheses are below:

4.1. Research Question 1

Will the addition of mushrooms to a cookie formula result in detectable sensory differences when presented to a panel of untrained consumers?

4.2. Research Question 2

Will reported protein powder or fiber consumption be associated with likelihood to purchase or consume food items containing notable amounts of protein or fiber?

4.3. Research Question 3

Will reported preference for mushrooms be associated with likelihood to purchase or consume food items fortified with mushrooms?

4.4. Research Question 4

Will preference for mushrooms be associated with determination of the experimental (mushroom-containing) sample in a triangle test?

5. Method

5.1. Formula

Two chocolate chip cookie formulations (control and experimental) were developed for this study: Table 1 and Table 2 contain the formulation information, including ingredients, respective ingredient quantity in grams, and a percentage of formula in descending order.

Table 1. *Mushroom Chocolate Chip Cookie Formula (Experimental Formula).*

Ingredient	Quantity (grams)	Percentage (%)
Banana	118	19.65
Brown Rice Flour	79	13.16
Non-Fat Plain Greek Yogurt	75	12.49
Organic Coconut Flour	60	9.99
Brown Sugar	48	7.99
Orgain® Organic Plant Based Vanilla Bean Protein Powder	46	7.66
Whole Fresh Egg	44	7.33
White Button Mushrooms	35	5.83
Dark Chocolate Baking Chips	28	4.66
Vanilla Extract	19.5	3.25
Almond Butter	16	2.66
Whole Grain Wheat Flour	15	2.50
Honey	10.5	1.75
Stevia	4	0.66
Baking Powder	2.5	0.42
Total	600.5	100.00

Table 2. *Chocolate Chip Cookie Formula (Control Formula).*

Ingredient	Quantity (grams)	Percentages (%)
Banana	236	20.87
Brown Rice Flour	158	13.97
Non-Fat Plain Greek Yogurt	150	13.26
Organic Coconut Flour	120	10.61
Brown Sugar	96	8.49
Orgain® Organic Plant Based Vanilla Bean Protein Powder	92	8.13
Whole Fresh Egg	88	7.78
Dark Chocolate Baking Chips	56	4.95
Vanilla Extract	39	3.45
Almond Butter	32	2.83
Whole Grain Wheat Flour	30	2.65
Honey	21	1.86
Stevia	8	0.71
Baking Powder	5	0.44
Total	1131	100.00

5.2. Instrument

The data collection instrument featured a scorecard for a triangle difference test for evaluation of the control and experimental formulas, as well as a space to provide qualitative feedback on perceived differences between formulations. Additionally, the instrument used for data collection included personal and descriptive questions including age, gender, mushroom likeability, frequency of fiber and protein powder consumption, and likelihood of purchasing either cookie formula.

5.3. Participants

Twenty students and faculty members of Southeast Missouri State University (SEMO) volunteered to participate in the sensory evaluation, including 14 females and 6 males, ages 9 – 41. The evaluation was conducted in a cafeteria style setting.

5.4. Sample Preparation

Twenty groups of samples were prepared for the sensory evaluation, with each sample group including two control samples and one experimental sample.

Samples were presented on disposable, white plates that were each labeled with a three-digit numeric code corresponding to one of the two formulations. Each participant received three plates with the following coding convention: 137 (control formula), 312 (control formula), and 210 (experimental formula).

Each sample of the control formula was approximately 28 grams. Samples of the experimental formula were approximately 30 grams. Each cookie dough droplet was flattened with the back of a spoon to ensure that each would bake evenly and ensure visual uniformity.

5.5. Sensory Evaluation

A trio of samples was displayed for each participant in a triangle formation, with the scorecard in front of each sample group. Each participant was provided a glass of water to drink in between samples for the purposes of cleansing their palate. Participants were asked to complete the instrument and submit to the primary investigator.

6. Results

6.1. Research Question 1

When presented to a panel of untrained consumers, the addition of mushrooms did not result in detectable sensory differences. Results of the sensory evaluation are displayed in Table 3. Eleven of the twenty participants correctly identified the experimental sample A chi-square goodness of fit test indicates that this frequency was not statistically significant ($p = 0.061$), which indicates that the experimental formula was not substantially different from the control formula. The addition of 5.83% white button mushrooms to the control formulation did not result in meaningful sensory differences.

Table 3. *Different Sample Cookie Responses (n = 20).*

	Frequency	Percent	Cumulative Percent
Correct (210)	11	55.0	55.0
Not Correct (137)	6	30.0	85.0
Not Correct (312)	3	15.0	100.0
Total	20	100.00	
Chi Square Goodness of Fit Results			
Chi-Square (χ^2)	3.51		
Degree of Freedom	1		
p	0.061		

6.2. Research Question 2

A correlation analysis indicated that the relationship between reported fiber consumption and the likelihood to purchase the product(s) were not significant. Similarly, the relationship between reported protein consumption and purchase likelihood was not significant. These results are presented in Table 4.

Table 4. *Fiber & Protein Consumption* and Likelihood of Purchasing Any Sample**.*

	R	*p*
Fiber Consumption & Purchase Likelihood	0.265	0.260
Protein Consumption & Purchase Likelihood	0.392	0.088

*Fiber and protein consumption data was collected with the following instrument items:
How often do you consume high fiber food items?
How often do you consume protein powder?
Responses for these items were coded: Never (0), Rarely (1), Occasionally (2), Sometimes (3), Often (4), Very Often (5)
**The likelihood that a participant would purchase one of the samples tested during the evaluation was collected with the following instrument item:
Likelihood of purchasing any of the cookie samples?
Responses for this item were coded: Very Unlikely (0), Unlikely (1), Slightly Unlikely (2), Slightly Likely (3), Likely (4), Very Likely (5)

6.3. Research Question 3

The data suggests that the preference for mushrooms was associated with the likelihood to purchase mushroom-fortified items. The relationship between the reported likeability of mushrooms and the likelihood of purchasing mushroom fortified products is displayed in Table 5. The Pearson correlation analysis suggests that mushroom likeability and purchase likelihood of mushroom fortified items have a strong, positive, significant correlation.

Table 5. *Mushroom Likeability* and Likelihood of Purchasing Mushroom Fortified Products**.*

	R	*p*
Mushroom Likeability & Purchase Likelihood	0.732	$p < 0.001$

*Mushroom likeability was collected with the following instrument item:
How would you rate your likeability of mushrooms?
Responses for this item were coded: Dislike Extremely (0), Dislike (1), Dislike Slightly (2), Like Slightly (3), Like (4), Like Extremely (5)
**Likelihood of purchasing mushroom fortified product was collected with the following instrument item:
Likelihood of purchasing products fortified with mushrooms in the future?
Responses for this item were coded: Very Unlikely (0), Unlikely (1), Slightly Unlikely (2), Slightly Likely (3), Likely (4), Very Likely (5)

6.4. Research Question 4

The data suggests that there is not a meaningful relationship between mushroom preference and ability to correctly detect the experimental sample. This relationship is displayed in Table 6. A chi-square measure of association analysis suggests that mushroom likeability and experimental sample detection were not significantly associated.

Table 6. *Mushroom Likeability and Ability to Determine Experimental Sample.*

	Value
Chi-Square (χ^2)	5.859
Degrees of Freedom	5
p	0.320

6.5. Additional Results of Interest

Results of the hedonic evaluation of all three samples are provided in Table 7 (both control samples and the

experimental sample). Thirty five percent of participants reported that the experimental formula was preferred.

Table 7. *Overall Favorite Cookie Sample.*

	Frequency	Percent	Cumulative Percent
137	5	25.0	25.0
210	7	35.0	60.0
312	8	40.0	100.0
Total	20	100.00	

7. Discussion

The addition of white button mushrooms did not result in significant sensory differences among the consumer panel. It is worth noting that white button mushrooms are one of the more insipidly flavored mushroom varieties, which is likely why they did not contribute to the participants' ability to decipher between the two formulas.

The qualitative data collection revelated that some participants perceived the experimental formula to have more moisture, which may have been due to using fresh produce. To increase the covertness of mushrooms in cookie products, future research should evaluate the use of dried and milled mushroom flour.

The results indicate that there is a not significant relationship between frequency of protein powder and fiber consumption and participant likelihood to purchase the high-fiber, high-protein cookie formulas. However, the reported preference for mushrooms was significantly related to their likelihood of purchasing or consuming mushroom fortified foods in the future. This may be due to the growing interest of the purported health benefits of mushrooms and/or sensory preferences.

Seven out of twenty participants identified the mushroom-fortified cookie as their preference among the samples. Interestingly, this does not necessarily align to the data regarding of mushroom likeability, which may suggest that mushrooms have potential utility has a fortification ingredient in foods that would not be associated with commonly recognized culinary uses of mushrooms (i.e. cookies). This is further supported by the data reflected in participants' ability to guess the correct mushroom cookie sample compared to mushroom likability: there was not a significant association between preference for mushrooms and the ability to correct the mushroom-containing sample.

Many previous research studies regarding mushroom usage in baked food products have used methodologies that involve measuring various ratios of mushrooms in formulas [1, 10, 11]. This study measured the difference between a mushroom-containing formula and one with zero mushrooms, which further illustrates the potential utility of mushrooms in food items as an undetectable ingredient.

In prior studies, researchers have used milled mushroom flour as an ingredient or as part of the flour portion of a recipe when incorporated into a baked food product [1, 10, 11]. This study used fresh, chopped mushrooms incorporated into the batter of cookie dough to test the likability and distinction of their addition.

Research by Biao et al. in 2019 used consumer panelists who were trained to evaluate the characteristics of the baked food products, such as texture and flavor [1]. This study used a panel of students and faculty attending Southeast Missouri State University who had no previous training on sensory analysis of these specific food products. Use of an untrained panel of participants perhaps provides a clearer picture of the general public and the potential success with mushroom-fortified items in the retail market.

8. Conclusion

Certain limitations during the sensory evaluation may have impaired the participant's ability to evaluate the cookies properly. The timing of the sensory evaluation (3:00 PM), the presence of competing aromas from other products undergoing sensory evaluation, and noise may have impacted participant perceptions of the samples. Repetition of this exploratory study would be contributory to the literature.

Future research exploring the incorporation of mushrooms into popular food items can benefit from the trials of this research study. To establish a more imperceptible product fortified with mushrooms, using a milled version seems to contribute less moisture and texture. Using fresh mushrooms may be useful in alternative recipes, but dried and milled mushrooms may be best with use in baking products.

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