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MAZUROVA ARINA

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Hungarian University of Agriculture and Life Sciences

Budapest Campus

Institute of Food Science and Technology

Department of Livestock Product and Food Preservation Technology

**Development of Meat-Reduced Mushroom-Based
Burger Patty**

MAZUROVA ARINA

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1. Introduction

A recent shift toward healthier and more sustainable dietary choices can be noticed, as the trends of food production are being reconsidered globally. Nowadays, one of the main concerns is the overconsumption of meat, especially red meat. While it is known for being nutritious, when consumed excessively and cooked at high temperatures, red meat can potentially lead to a wide range of health problems, including cardiovascular diseases, obesity, and some types of cancer. In this regard, there is a trend among many individuals to reduce or eliminate red meat from their diets. The alternative option for them is usually a vegetarian or plant-based diet.

Nevertheless, this sudden change can pose particular problems, with the consequences mainly stemming from the lack of essential micronutrients, such as vitamin B12, iron, and zinc. Besides, many consumers face many difficulties when giving up the rich variety of flavours typically associated with meat-based products. Mainly, it goes for products like burger patties – they are strongly tied to convenience and taste preference.

Everything mentioned above led to the development of a growing interest in hybrid food solutions, where meat is partially replaced with plant-based components, aiming to reduce the health risks and impact on the environment, with a minimal effect on flavour and texture. Mushrooms stand out as the most widely used ingredients for partially replacing meat. The reasons for this are their favourable nutritional profile, which includes fibre, antioxidants, several B vitamins (niacin, riboflavin, and pantothenic acid), as well as their umami-rich taste and meat-like texture. Moreover, they contain a lower amount of fat and cholesterol compared to meat. It must also be mentioned that they can improve the texture of the final product, making it juicier.

The investigation of the techno-functional, nutritional, and sensory characteristics of partially meat-based mushrooms can lead to the development of healthier, more sustainable food products. The present research stands on the point that mushrooms can serve not only as a flavour enhancer or extender, but also as an essential ingredient to be combined with meat in different consumer markets. The hybrid food solution can be beneficial for meat processing companies: it reduces costs by using less raw meat while preserving consumer satisfaction by maintaining almost the same taste and texture profiles.

2. Aim of the Study

The research investigates the techno-functional, physical, and sensory properties of a mushroom-based burger patty with reduced meat content, aiming to develop a nutritionally valuable product for consumers who wish to maintain their traditional eating habits. The research used ground beef as its base meat component because it remains a popular choice for burger production among consumers. The research selected oyster mushrooms (*Pleurotus ostreatus*). They possess a distinctive flavour and favourable texture and are both available and affordable. The research involved preparing 11 different patty mixtures, which decreased the meat content by 10% increments from 100% meat to 0% meat while substituting oyster mushrooms proportionally. The techno-functional properties were evaluated through rheological measurements and yield evaluations to determine the product's processing behaviour and industrial feasibility. The research team conducted instrumental colour analysis and visual shrinkage measurements to determine product consistency and appearance while assessing shelf appeal. The research used statistical methods to determine how rheological measurements and physical properties related to each other in different sample formulations. Consumer testing evaluated taste and aroma along with overall acceptability to determine the palatability and market potential of the developed patties. This research examines the practical application of this hybrid product as a nutritional supplement for human diets. The research investigates how consumer acceptance of mushroom-enriched burger patties relates to their techno-functional and physical attributes.

3. Literature Review

3.1 Drivers of meat consumption

Understanding the reasons behind consuming specific types of foods is a crucial step for improving health and environmental outcomes. For some people, there may be no dietary alternatives to animal-sourced food. For example, nomadic pastoralists in desert and semidesert environments, as well as traditional Inuit communities in the Arctic, are limited in their farming and hunting activities due to the scarcity of land with suitable soil for growing plants and the limited opportunities to purchase products. In other populations, on the other hand, there exists a problem of people's inability to buy and therefore consume generally considered desirable amounts of meat products. It must be stated, however, that at the present time, the opportunity for a large proportion of the global population to purchase and consume meat products is higher than it has ever been in history (Godfray et al., 2018).

In addition to price, there are many factors behind making decisions to consume meat. Innate food preferences probably evolved in an environment where food scarcity was a constant risk. A natural desire for energy-dense and nutrient-rich food once promoted survival, but today it may lead to diseases such as overconsumption (Drewnowski et al., 2012; Berridge et al., 2010).

When it comes to shaping diets, biological and psychological factors co-exist in a constant interplay with each other: nowadays, the decision about purchasing meat is shaped not only based on affordability, but also a wide range of factors, including convenience, social and cultural values, dietary habits (Marteau et al., 2017).

As it has been partly discussed previously, economics plays a very significant role in shaping diets. Livestock constitutes around 40% of agricultural output by price, with subsequent processing and retailing being substantial economic sectors in most countries. The meat production industry has a considerable political influence and can invest large amounts of money into advertising and marketing (Nestle et al., 2007).

3.2 Meat Diet, effects on health

The dominating framework through which studies on estimating the impact of meat consumption on health in the long term are conducted is epidemiological cohort studies in

which tens of thousands of participants report their dietary intake, with their health status being monitored over the course of years. The conclusions are based on the identified correlations between meat consumption and the risk of disease. The results of these studies, however, must be interpreted with great care to account for potential outside factors. Meta-analyses that aggregate findings from individual cohort studies can offer estimates. However, their reliability is compromised if they merge data from dissimilar studies or inherit the same biases present in the original research (Barnard et al., 2017).

Meat provides a wide range of essential nutrients, including protein and micronutrients such as iron, zinc, and vitamin B₁₂. With a balanced diet, there exists a possibility to obtain a sufficient intake of these nutrients without consuming meat (Appleby et al., 2016; Orlich et al., 2013). However, in lower-income countries, access to alternative nutrient-dense foods may be limited; therefore, it is nearly impossible for the population to maintain diets low in meat without the risk of malnutrition (Dror et al., 2011; Jackson et al., 2016).

Extensive studies and meta-analyses conducted in the Western wealthy countries steadily show that mortality rates tend to be higher when it comes to the part of the sample who follow a diet rich in both red and processed meat than in those with low meat intakes, whereas no or moderate inverse correlations have been observed for poultry (Rohrmann et al., 2013; Etemadi et al., 2017; Sinha et al., 2009; Wang et al., 2016).

3.2.1 Meat Diet, diseases Risks

The strongest evidence of the risks connected to high consumption of meat is its correlation to colorectal cancer. Due to the evidence of a link between meat consumption, the World Health Organisation's International Agency for Research on Cancer (WHO IARC) has classified processed meat as carcinogenic to humans, with red meat classified as probably carcinogenic to humans (Bouvard et al., 2015). IARC estimates that 34,000 cancer deaths per year worldwide can be attributed to diets rich in processed meat. If the reported associations with red meat were proven to be causal, then diets high in red meat could be responsible for 50,000 cancer deaths per year worldwide (IARC, 2015). The average intake of processed meat in Western Europe [26.4 g day; (Micha et al., 2015)] would, based on the IARC analysis, lead to a 9% [95% confidence interval (CI) 5 to 14%] increase in colorectal cancer risk. Components in meat that might be carcinogenic include heme iron, N-nitroso compounds, heterocyclic aromatic amines, and polycyclic aromatic hydrocarbons, which are formed when meat is cooked at high temperatures (Bouvard et al., 2015).

Consumption of processed meats is also associated with risk for several other diseases. For example, a recently conducted meta-analysis reported that high intakes of processed meat are associated with a moderate increase in the risk of mortality from cardiovascular diseases (Rohrman et al., 2013; Wang et al., 2016). Several factors could explain the observed association between high meat intake and the risk of the disease. Firstly, red and processed meats may increase risk due to the high saturation of fatty acids, which raises low-density lipoprotein cholesterol. Secondly, the high salt levels present in processed meat might raise blood pressure; other factors could include the generation of trimethylamine N-oxide from L-carnitine in meat (Wolk, 2017; Wang et al., 2011).

Recent studies have also suggested that high intakes of processed meat are associated with an increased risk for other chronic diseases, such as diabetes (Wolk, 2017) and weight gain in adults (Vergnaud et al., 2010).

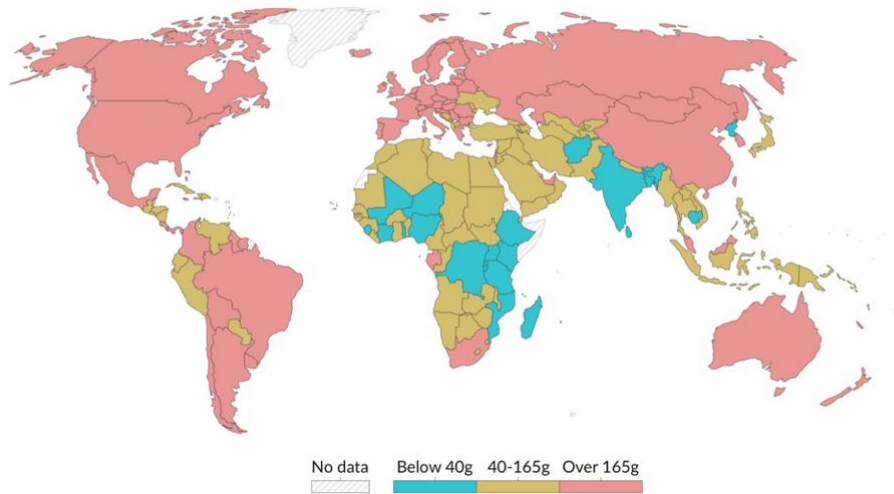
3.3 Recommended meat intake

Currently, various national and international bodies recommend introducing a maximum limit of meat consumption in order to maintain a good state of health. For example, the World Cancer Research Fund recommends consuming less than 500 g of meat a week, and population average consumption should not exceed 300 g a week, in each case, minimising the presence of processed meat in the diet (WCRF, 2017). The Global Burden of Disease project (GBD) suggests maintaining an intake of no more than one 100-g portion a week to reduce the possibility of developing a disease related to meat consumption (Forouzanfar et al., 2015).

Figure 1. Daily meat consumption per person worldwide, 2021

Daily meat consumption per person, 2021

Daily meat consumption is shown relative to the expected EU average of 165g per person in 2030. This projection comes from the livestock antibiotic scenarios from Van Boeckel et al. (2017).



High consumption of meat, particularly red and processed meat, may pose health risks to consumers and increase the likelihood of various diseases and higher mortality (Rohrman et al., 2013). However, it is important to consider the potential effects and consequences of eliminating meat from the diet.

3.4 Dietary characteristics of vegetarian diets

Vegetarians are defined as individuals who do not eat any meat, poultry or fish. Vegetarians are subclassified as lacto-ovo vegetarians, who eat dairy products and/or eggs, and vegans, who do not eat any animal-sourced products. Since vegetarian diets are defined by what they do not contain, the actual composition of vegetarian diets is widely varied. For the present review, the discussion is primarily based on the observed average diet of vegetarians as described in published reports, mainly for individuals living in affluent Western countries (Key et al., 2006).

3.4.1 Vegetarian diets, effects on health and development

A well-planned vegetarian diet is considered to be adequate for all stages of the life cycle (American Dietetic Association and Dietitians of Canada, 2003), but growth and development in vegetarians are poorly documented epidemiologically. New data on 390 lifelong vegetarians in EPIC-Oxford (Rosell et al., 2005) found that the height for both genders and age at menarche for women did not differ significantly between those who became vegetarian at age 20 and lifelong vegetarians (Rosell et al., 2005).

Studies of Western vegetarians have reported consistently that vegetarians have lower BMI (Body Mass Index) than non-vegetarians, and the mean difference in BMI is about 1 kg/m² (Key et al., 1999); the proportion of vegetarians who are obese is also lower than that of non-vegetarians (Key & Davey, 1996). The debate on the reasons for this difference has not been concluded, but it is possible that the difference in the composition of the diet, such as higher fibre and lower protein intake, may be the main drivers of the difference (Spencer et al., 2003).

The bone health of vegetarians has been of interest, but still, the data is scarce. Calcium intake of lacto-vegetarians is similar to that of non-vegetarians. In contrast, vegans have substantially lower Ca intake than the reference group, unless they consume a lot of Ca-rich plant foods (kale, collard greens, arugula, etc.). It has been suggested that omitting meat products from the diet may be beneficial due to reduced 'acid load', but the role of this factor is not well understood and remains actively discussed (New, 2004). Early results from EPIC-Oxford show that there is no difference in fracture rates between vegetarians and non-vegetarians; however, they did highlight the importance of consuming enough Calcium in order to reduce the risk of fractures (Key et al., 2006).

3.4.2 Vegetarian diets, disease risks

The dietary patterns characterised as vegetarian are associated with reduced incidence of colorectal cancers (Key et al., 2006).

Typically, in addition to lower intake of animal products, vegetarians eat less refined grains, added fats, sweets, snack foods, and caloric beverages. However, vegetarians consumed increased amounts of a large number of plant foods. Such patterns may reduce hyperinsulinemia, which has been postulated to be a cause of increased colorectal cancer risk (McKeown-Eyssen, 1994; Giovannucci, 2003; Tran et al., 2006; Choi et al., 2012; Wei et al., 2005; Michaud et al., 2005; Tsai et al., 2012; Bao et al., 2010).

From the information collected, both diets appear to have the potential of being hazardous, and thus, it is important to compare the two in order to get a clearer picture of their effects.

3.5 Comparison of vegetarian and meat-based diets

3.5.1 Land resources

More than 99.2% of the food is produced on the land, while <0.8% is from oceans and other aquatic environments. The use and availability of the land is a growing concern with the rate of soil erosion and degradation in the United States and other parts of the world.

Every year, 90% of the US cropland loses soil at a rate 13 times above the sustainable rate of 1 ton/ha/y. Also, US pastures and rangelands are losing soil at an average of 6 tons/ha/y. About 60 % of the pastures in the United States are overgrazed and are prone to accelerated erosion (Pimentel et al., 1998).

The concern about high rates of soil erosion in the United States and other parts of the world is evident when it is considered that it can take as much as 500 years to replace 25 mm of lost soil. Some of the nutrients lost through soil erosion can be replaced through the use of commercial fertilisers, but this requires much energy from fossil fuels (Pimentel et al., 1998).

3.5.2 Water resources

Agriculture is the largest consumer of water in the United States. Western agricultural irrigation is responsible for approximately 85% of water consumption. The water used in producing various foods and forages is between 500 and 2,000 litres per kilogram of produce. For example, a hectare of US corn uses more than 5 million litres of water during the three-month growing season. If irrigation is required, more than 10 million litres of water must be applied. Even with 800-1000 mm of annual rainfall in the US Corn Belt, corn often experiences water deficit in July when the corn grows most rapidly (Pimentel et al., 1997).

Producing 1 kg of animal protein requires about 100 times more water than producing 1 kg of grain protein (Pimentel et al., 1996). Direct use of water by livestock is only 1.3% of the total water in agriculture. However, when the water used for forage and grain production is also included, the water use in livestock production is drastically increased. For example, 1 kg of beef may require as much as 13 kg of grain and 30 kg of hay (Pimentel et al., 1980). This much forage and grain requires about 100,000 litres of water to produce the 100 kg of hay, and 5,400 litres for the 4 kg of grain. On rangelands for forage production, more than 200,000 L of water are required to produce 1 kg of beef. The amounts of water used in animal production are different depending on the type of animal. Broiler, for example, can be produced with 2.3 kg of grain for each 1 kg of feed conversion (Thomas, 1987).

3.5.3 General sustainability

Both the meat-based average American diet and the lacto-ovo-vegetarian diet are heavily dependent on fossil energy input and are therefore not sustainable in the long run.

However, the meat-based diet is more energy-, land- and water-intensive than the lacto-ovo-vegetarian diet. In this sense, the lacto-ovo-vegetarian diet is more sustainable than the average American meat-based diet (Pimentel et al., 2003).

The primary threat to the future and the US's natural resources is population increase. The population of the United States of 285 million people is expected to double to 570 million in the next 70 years, which will put more pressure on the limited energy, land and water resources. These resources are going to be shared among an ever-increasing number of people (Pimentel et al., 2003).

3.5.4 Total mortality

Total mortality appears to be similar among vegetarians and non-vegetarians; in the pooled analysis of five prospective studies, the death rate ratio in vegetarians compared with non-vegetarians is 0.95 (Key et al., 1999), and a subsequent analysis in EPIC- Oxford shows a death rate ratio of 1.05 (Key et al., 2003). The calculation of the standardised mortality ratio in the three UK cohorts shows that the mortality in the vegetarians is lower than that of the general population of England and Wales. The standardised mortality ratios (SMRs) are 49, 47, and 45, respectively for the Health Food Shoppers study, the Oxford Vegetarian Study, and EPIC-Oxford, Low SMRs are seen in cohort studies of volunteers but these low values for the vegetarians do demonstrate that in general terms their health is good (Key et al., 2006).

After comparing the advantages and disadvantages of vegetarian and meat-based diets, along with the high meat consumption trends in developed countries, it can be concluded that there is a need to develop a reduced-meat product. This concept involves a patty with lower meat content, replaced by a mushroom component.

3.6 Ground beef

Beef that is ground by the USDA standards includes only fresh or frozen beef with no water, phosphates, binders, or extenders added. The usual source of ground beef is beef trimmings, the pieces produced when cutting and fabricating beef into smaller pieces. The highest fat content for ground beef is 30% (70% lean) and is expressed as a lean-to-fat ratio, such as 80/20 or 90/10 (USDA, 2023). These ratios help consumers select ground beef that matches their cooking needs; for example, higher fat content offers a juicier texture ideal for burgers, while leaner options are suited for recipes like tacos or sauces that benefit from

minimal grease. Ground beef must not include extra fat unless it is labelled as "hamburger," which allows the addition of separate beef fat (USDA, 2023).

Ground beef's distinct colour is due to myoglobin, a muscle protein that reacts with oxygen. The nutritional value of ground beef includes protein, iron, and zinc, with levels slightly varying based on fat content, providing flexibility in nutritional and culinary applications (USDA, 2023; Texas A&M Meat Science, 2023).

3.6.1 Ground beef packaging

Ground beef was formerly a by-product, that is, the trimmings from reducing muscle to edible portion size. Some muscle cuts are now being ground to meet the demand for ground beef as opposed to using the beef for this purpose only. The bacterial contamination is higher in the beef as it is cut into smaller pieces. It is distributed further into the surface and sub-surface layers, and thus offers a rich source of nutrients even under cold storage conditions. Pork is not often reduced to ground fresh form but pension is being taken to process and sell poultry meat and even as a cheaper alternative to beef. Most of the ground beef is processed in the abattoirs and packed under reduced O₂ conditions for storage at refrigerator temperatures to reduce the rate of microbial growth. The most common method of packaging is in chubs, which are flexible, gas-impermeable tubes that have metal ends. In this case, the pressure while packing forces most of the air out of the ground beef and since there is no headspace in the package, there is little air in the package to support the growth of aerobic spoilage microorganisms like *Lactobacillus* and *Leuconostoc* spp. At the retail level, the coarse ground beef is finely ground to restore the desirable red colour and provide the consumer with the desired product (Aaron, 1999).

3.6.2 Categories of ground beef products

It is important to distinguish the different categories of ground beef products that can be purchased in retail outlets. Products labelled as ground chuck, ground round, or ground sirloin are ground beef products that contain only skeletal muscle and skeletal trimmings that originate from the muscle primal specified on the label. As an example, a ground round product contains only skeletal muscle and skeletal trimmings from the round primal. A product labelled simply as ground beef is produced by combining skeletal muscle, skeletal trimmings, head meat trimmings and up to 25% of cheek meat. In addition to the components allowable in a ground beef product, products designated as hamburger can also contain added beef fat. Regular or coarse ground beef and hamburger can be purchased

at varying ratios of lean to fat (eg, 80% lean/20% fat), which provides an array of products with differing price points that are suitable for a variety of applications and personal preferences. Unlike water, seasonings, phosphates, and other additives (eg, extenders or binders) are allowable in ground beef and hamburger products (USDA-FSIS, 2013a; Unruh et al., 2016).

3.6.3 Nutrient and chemical composition of ground beef

An analysis of fast-food hamburgers from eight different restaurants by Prayson et al. (2008) showed that hamburgers are primarily water (49%) and that the ‘meat’ portion of the samples ranged from 2.1% to 14.8%. The ‘meat’ portion of the samples included skeletal tissue, connective tissue, blood vessels, peripheral nerves, adipose tissue, bone, cartilage, and plant material (Prayson et al., 2008). Ground beef is nutrient-dense, accounting for high percentages of daily values of total fat, saturated fat, cholesterol, protein, and vitamins B12 and B6 (USDA-ARS, 2015). Sufficient levels of various minerals, such as phosphorus and potassium, are also bioavailable in ground beef (USDA-ARS, 2015).

3.7 Defining a burger: essential elements of the patty

A burger’s quality is determined by its texture, shape, consistency, and appearance, all of which influence both the sensory experience and consumer satisfaction. Each of these elements can be controlled through specific processing techniques, allowing for different types of burgers that appeal to varied consumer preferences (Field et al., 2020).

3.7.1 Texture and taste

The texture of a burger significantly impacts the taste experience, mainly due to the grind size and orientation of meat proteins, particularly collagen fibres. Collagen orientation affects the patty’s juiciness and bite, as it determines how much air is retained within the meat mass (Hughes et al., 2018). By aligning collagen fibres in a specific direction, it is possible to control the meat’s firmness and density, allowing for either a softer or firmer bite. Larger fibre sizes, for instance, create more space for air pockets, enhancing juiciness and giving the burger a more substantial texture (Chin et al., 2020).

3.7.2 Shape consistency

Controlling the contraction of collagen fibres during cooking is crucial to the appearance of the burger. During cooking, collagen fibres shrink, which may lead to a reduction in the size of the patty. However, by aligning these fibres vertically, the reduction in diameter is at the expense of height. This approach helps the burger to maintain its shape prior to cooking, to give the consumer a good impression, and to reduce the chances of the consumer being dissatisfied with the shape of the burger. An adverse finding of this study is that the appearance of the patties before and after cooking has an important role in the decision-making process of the consumers (Tornberg et al., 2005).

3.7.3 Visual appeal

Appearance is also an important factor both before and after cooking, and is a key factor in the decision-making process of the consumer. Characteristics such as the fibre orientation, grind size and surface structure of a burger are crucial in determining its visual quality and quality perception in the mind of the consumer, a positive correlation being observed for visual quality with consumer perceived quality. Recent work has shown that burgers with a more uniform surface and colour are perceived to be fresher and more attractive (Tornberg et al., 2005).

3.7.4 Different types of burgers

Burgers are made in different ways to meet the taste and texture preferences of the consumer. The Standard Burger has a traditional texture with a lightly aligned fibre structure, which is obtained by a relatively mild grinding and mixing process and avoidance of high-pressure forming in order to maintain the initial raw material shape and size. The Tender-Fresh Burger, however, has a soft and juicy texture with the fibres arranged in the vertical direction. This orientation also improves the tenderness by allowing the individual columns of meat to separate easily when bitten, and also reduces the height by which the patties shrink when cooked (Tornberg et al., 2005).

For a lighter texture, the Homestyle Burger employs smaller vertical fibres to reduce density, resulting in a looser bite that minimises shrinkage and maintains visual appeal. This structure caters to consumers seeking a balance of tenderness and texture. Meanwhile, the Butcher Burger features a distinctive “angel-hair” or interwoven fibre pattern that traps air, contributing to a juicy texture, faster cooking, and an artisanal look.

This interlaced structure not only enhances juiciness but also aligns with consumer demand for premium, high-quality burgers (Tornberg et al., 2005).

3.8 Burger patty production factors

To obtain a high-quality and homogeneous product, there are several important factors that need to be taken into consideration, such as fat content, product weight, temperature, and foreign body rejection. All factors are significant in achieving a uniform product while simultaneously maximising yield, quality, and safety (Tornberg et al., 2005).

The fat-to-lean ratio is important in the beef patties in terms of texture, moisture and flavour, and it has been found that a fat content of between 15-20% gives the best taste and juiciness while a lower content gives a dry and dense product. At present, X-ray technology and interferometric spectroscopy can be used for the accurate control of fat content; thus, the quality of the product is improved, and there is minimal product waste. This is also important in the control of product weight to ensure that the products are of the right size and weight for portion control and cooking purposes. This can be done by the use of forming machines or vacuum stuffer portioning. This paper shows that controlling density in forming machines improves weight accuracy, which is cost-effective and produces quality products. Temperature regulation is also an important factor because the optimum processing temperature of -2 to 0°C (28-32°F) is ideal for forming and cooking, to make the patties firm and malleable. This can be accomplished with the use of fresh and frozen meat or with the help of nitrogen cooling to maintain the meat quality and safety. In addition, foreign body detection is critical in any food company since contaminants such as metals and bones are dangerous to health. They can prevent contaminants up to 99% in the final products using metal detectors and X-ray systems. It also reduces safety risks and production waste (Tornberg et al., 2005; López-Campos et al., 2018).

3.9 Continuous production line for ground beef patties

Today, the continuous production line for ground beef patties is indispensable in the large-scale production of food products with the required level of quality and productivity. This line incorporates several technological advancements that enable it to handle the complete process from the reception of the raw meat up to the cooking, quality control, and packaging. Such systems respond to increasing consumer demand for safe, high-quality

and uniform products, while also addressing economic imperatives for cost-effectiveness and reduced labour dependency in the food industry (Barbut, 2013).

The production line starts with the grinding section, in which the raw beef and other ingredients, if desired, are cut to the desired grind size. Industrial grinders are utilised to cut meat at a rapid rate and produce a uniform product in terms of texture and taste across different batches. At this stage, salt, preservatives or any other flavour enhancer can be incorporated into the product to achieve the desired product formula and to increase the shelf life of the product. These high-precision automatic dosage systems ensure that these ingredients are added in the right measure, preventing the possibility of making errors, and at the same time guaranteeing that every batch is safe and fit for consumption as per the requirements of the regulations (Barbut, 2013).

The meat is then conveyed to the patty-forming station from the ground meat using conveyors. Modern forming machines use hydraulic or mechanical pressure to give the ground beef the shape and size of a patty. This is so because size is a crucial and important quality and acceptance parameter of the consumer. Some forming machines are programmable and can be set to specific patty sizes to suit different product lines or consumer tastes. Furthermore, the automation features that the machines offer make it possible to produce at rates that would be impossible to achieve by hand (Barbut, 2013).

The cooking stage is another important stage that includes processes such as grilling, steaming or baking, depending on the product type. The ovens or grills that are automated control the temperature and time of cooking to guarantee that the patties are cooked to the required internal temperature to kill pathogens. Modern cooking equipment is often equipped with temperature sensors and monitoring systems that can provide real-time data and control. These systems, in addition to improving food safety, also help in the formation of the desired texture and juiciness and thus the sensory quality of the final product (Barbut, 2013).

The patties then move on to the cooling or freezing area right after the cooking stage. Chilling is, however, very important to stop the growth of bacteria and to preserve the product quality. The standard freezers are cryogenic or mechanical freezers, and these systems are intended to hold patties in the temperature “danger zone” (4°C to 60°C) for as little time as possible, during which time bacteria can grow. Temperature is, however, important to the extent that one has to achieve it in order to meet the shelf life, especially

when the product is to be transported to market over a large area. Like the other phases of the production line, this stage is often highly automated, thus significantly reducing the potential of contact between the product and the human body and the chances of contamination (Barbut, 2013).

The role of automated quality control systems located within the line is to guarantee product quality and safety. Some systems use optical sensors and imaging technology to measure patty attributes such as colour, shape and size. Some production lines are also installed with X-ray or metal detection units to make sure that no foreign materials are incorporated in the final product. These quality control systems can work at very high rates, and in the case of patties, they can examine several hundred patties per minute and reject those that do not meet the set standards. Such automation helps in avoiding wastage and, at the same time, only the good patties get to the consumer (López-Campos et al., 2018; Tornberg, 2005).

3.10 Comparative analysis of double-sided grilling and oven baking in meat processing

The properties of meat products change significantly according to the cooking techniques used. Two prominent cooking techniques used in both home kitchens and industrial environments are double-sided grilling (DSG) and oven baking. The cooking process of DSG produces quick cooking and deep surface browning through direct heat application to the meat's dual sides, which occurs through contact with heated plates. Oven baking creates internal temperature uniformity through enclosed convective heat transfer while maintaining moisture content (Pathare & Roskilly, 2016). A mathematical model for predicting temperature profiles during DSG of meat patties was developed by Pathare and Roskilly (2016). The model showed that DSG produces faster heat penetration than single-sided methods, which results in shorter cooking times and potential commercial process advantages. Fast heat transfer during DSG operations tends to produce temperature inconsistencies throughout the meat. This usually happens due to failure to implement proper temperature management (Pathare & Roskilly, 2016).

The selected cooking technique impacts sensory characteristics that include tenderness, along with juiciness and flavour. Al-Moadhen et al. (2023) analysed different beef cuts in a study that compared grilling techniques against roasting methods, commonly known as the

oven-baking method. The evaluation showed that grilled samples received better scores for tenderness, juiciness, flavour and overall liking, except when testing the Topside cut, which displayed decreased tenderness during grilling. Sensory benefits of DSG on the quality of meat differ from one specific type of meat to another (Al-Moadhen et al., 2023).

The nutritional profile of food changes based on how meals are cooked because it affects both protein breakdown and fat levels. Olagunju et al. (2020) studied how grilling and boiling affect the nutritional characteristics of different meats from different animals. The research showed that in vitro protein digestion increased significantly after grilling, particularly in cow meat, compared to when using boiling as a cooking method. The combination of grilling with cooking losses resulted in reduced fat content in the final product (Olagunju et al., 2020).

The textural study of tilapia fish burgers by Bainy et al. (2015) demonstrated that grilled burgers showed higher shear force measurements, together with decreased water retention when compared to baked samples. The baked samples maintained their texture softness while retaining more moisture content, which matches specific product development requirements (Bainy et al., 2015)

3.11 Oyster mushroom

Mushrooms are macro fungus which has distinctive fruiting bodies that can either be epigeous or hypogeous (Chang et al., 1992). Due to a lack of chlorophyll in mushrooms, they cannot synthesise their food, so they depend on dead and decaying matter as their saprophytes. Moreover, it has the potential to solve many growing global problems like food demand, unemployment, environmental pollution, etc. Mushroom produces enough amount of quality and quantity food which is of high biological value and suits a wide range of groups from children to older people (Nongthombam et al., 2021).

Among the different types of mushrooms, the oyster mushroom is also one of the most cultivated species. Oyster mushroom (*Pleurotus ostreatus*) belongs to the family Agaricaceae and class Basidiomycetes. Oyster mushroom is known for its rich content of vitamin C and vitamin B complex, and its protein content varies from 1.6 to 2.5 percentage, along with mineral salts, which are essential for the human body (Randive, 2012).

Apart from its nutritional value, it is also known for its medicinal value in fighting diabetes and cancer (Sivrikaya et al., 2002). Due to its high potassium-to-sodium ratio, it is ideal

for people suffering from heart disease and hypertension (Sharma et al., 2013). Moreover, it has no cholesterol content since it is easily digestible (Oei, 2005). It can also cure anaemia because of the folic acid present in oyster mushroom (Randive, 2012). Mushroom species are known to have a wide range of metabolites such as antitumor, antioxidant, antitoxic, antiplatelet aggregating, antihyperglycaemic, antimicrobial and antiviral activities (Chang, 2007). Moreover, among the types of mushrooms, the oyster mushroom species, namely *Pleurotus ostreatus*, has antitumor activity (Chorvathova et al., 1993), while *Pleurotus cystidiosus* has strong antioxidant properties (Li et al., 2007).

Therefore, oyster mushroom cultivation has increased throughout the world because of its medicinal properties and its potential to grow at a wide range of temperatures and different agro-based residues. It also has wide adaptability to various agro-climatic conditions on different agricultural waste (Jandaik et al., 1995). Moreover, the substrates where the mushrooms were grown can also be used as biofertiliser for enriching the soil fertility, as animal feed and also as a feed for biogas production (Alice et al., 2004). As a reason, mushroom cultivation is known to be eco-friendly as it has no effect on the environment compared to other crop cultivation (Nongthombam et al., 2021).

3.12 Production of oyster mushroom

Mushrooms are grown mainly on waste materials like sawdust, composting materials, straw and garbage (Gbolagade et al., 2006). It is reported that mushroom cultivation was first started in France around the age of 1630, so to monitor different growth parameters of mushrooms, a series of experiments and studies have been conducted since then (Miles et al., 2004).

3.12.1 Agro-climatic requirements

The most suitable temperature for the growth of Oyster mushroom ranges from 20° to 30° C, and humidity ranges from 55-70%, for a period of 6-8 months in a year. The cultivation practices during the summer months can be done by providing the extra humidity required for its growth and development. Mushroom production requires multiple steps and is grown in favourable conditions, which are found in natural caves or in a well-controlled growth chamber (Sharma et al., 2013).

3.12.2 Substrate preparation

Mainly used substrates are organic materials like lignocellulosic farm waste, on which the growth of mycelium takes place to produce mushrooms. Substrates used include sawdust, rice bran, rice straw, wheat bran and wheat straw (Khare et al., 2018). Substrate preparation is known to be the most critical stage in the production process to ensure the occurrence of diseases is less, with better yield (Khonga et al., 2013). So as to eliminate potential competitors such as *Trichoderma* spp. and *Pleurotus* spp., substrate like grasses, sugarcane bagasse is pasteurised beforehand (Oseni et al., 2012). Pasteurisation can be done by using steam or by using hot water treatment ($\pm 70^{\circ}\text{C}$) on the substrate for a few hours. Soaking the substrates in water treated with benomyl (0.06g/L) tends to suppress the risk of *Trichoderma* spp (Gumede, 2008). Including commercial production and small-scale production of oyster mushroom, the treatments mentioned above can be applied and are affordable (Nongthombam et al., 2021).

3.12.3 Spawning of substrate

Spawn, which is used as a seed in propagation for mushroom production, is defined as a substrate in which mycelium is impregnated and developed (Woo et al., 2004). Spawn can be prepared from different carriers of grains such as wheat, sorghum, barley and rice (Khonga et al., 2013). It is reported that, compared to grains of wheat and barley, grains of sorghum are better mycelium carriers. The yield and biological efficiency can be increased by the adoption of the spawn, while the spawn running time gets reduced (Khare et al., 2018).

The quality of the carrier and moisture (60-70%) significantly affects the quality of the spawn as it determines the growth and colonisation of the mycelium on the substrate. The spawned substrate requires a certain temperature ranging from 25-30°C and a dark room, which satisfies the mycelia for proper growth and colonises the substrate (Nongthombam et al., 2021).

3.12.4 Incubation and fruiting

During the incubation period, temperature is optimised to 20- 250 °C in order to get the best results and kept in the incubation room without disturbance for 15-25 days, also depending on the size and conditions of the bags (Woo et al., 2004). At the time of fruiting, the Relative Humidity should be maintained at 70-85% by spraying or sprinkling water

into the gunny bags or on the sand spread on the floor (Sharma et al., 2013). At least 8-12 hours of sunlight are required at the time of fruiting. (Nongthombam et al., 2021).

3.12.5 Harvesting and yield

The mushrooms can be harvested by gently twisting the fruiting body before water spray. After first harvesting, the bags are kept in a growing chamber so that other mycelium can grow and produce more fruiting bodies, which can then be harvested again. The harvested mushrooms are then packed in perforated polythene bags for marketing. In a period of one and a half to two months, from 1 ton of paddy straw, around 500-700 kg of fresh mushroom can be harvested (Sharma et al., 2013).

4. Materials and Methods

4.1 Materials

The experiments were conducted at the Hungarian University of Agriculture and Life Sciences (MATE), Buda Campus, Budapest, Hungary. The raw ingredients used in the study included ground beef with a composition of 20% fat and 80% lean muscle meat, sourced from the brand “Regnum,” produced by SPAR Regnum Hungary Kft. Oyster mushrooms, used as a partial meat replacement ingredient, were purchased in raw, non-cultivated form from the “KORONA” brand, produced by Magyar Gomba Kertész Kft. Both raw materials were obtained from a SPAR supermarket.

4.2 Methods

4.2.1 Preparation of mixtures

For the preparation of the mixtures, which were subsequently used for further analyses and measurements, the raw ingredients were first procured. Following this, the mixture formation step was carried out. Both ground beef and oyster mushrooms were utilised in their raw state in a proportion according to the *Table 1.*, without the addition of seasonings or other additives, in order to obtain comprehensive and objective results.

Table 1. Meat-mushroom mixtures and their proportions in a single patty sample

Sample code number	Ground beef content (g)	Oyster mushroom content (g)	Total mass (g)
1. 100-0	100	0	100
2. 90-10	90	10	100
3. 80-20	80	20	100
4. 70-30	70	30	100
5. 60-40	60	40	100
6. 50-50	50	50	100
7. 40-60	40	60	100
8. 30-70	30	70	100
9. 20-80	20	80	100

10. 10-90	10	90	100
11. 0-100	0	100	100

The raw materials were weighed with precision using “ENTECH NWT-3K” scales, which had a measurement error of 0.001 kg. The ingredients were then combined for approximately 120 seconds according to the specified proportions for each sample, using a “Robot Coupe R2” mincer with a 2.9 L capacity. Upon achieving a homogeneous mixture, the samples were subjected to further processing steps, while a portion was retained in raw form for testing.

Following mixture formation, the cooking process was initiated. The mixtures were shaped into 100 g patties and labelled accordingly. Two distinct heat treatment methods were applied. The first method involved oven baking, wherein the samples were heat-treated for 15 minutes at a temperature of 170 °C using a “LAINOX VE051P” oven. After thermal processing, the samples were allowed to cool and were then used in subsequent experiments.

The second heat treatment method employed double-sided grilling using an “AMBIANO” cooking device for 6 minutes at an approximate temperature of 190 °C. Both cooking methods ensured that the final products reached the “well-done” stage required for testing.

4.2.2 Yield measurement

For the yield measurement, each patty sample was weighed before and after the heat treatment procedure. Every sample was intended to reach a weight of 100 g; however, minor deviations occurred due to measurement error. Each mixture was prepared in three parallel samples for each heat treatment method. The yield was calculated using the following formula:

$$Total\ yield\ by\ mass\ (\%) = \frac{m_2}{m_1} \cdot 100\%$$

Where:

m1: mass of the patty sample before heat treatment

m2: mass of the patty sample after heat treatment

4.2.3 Colour measurement

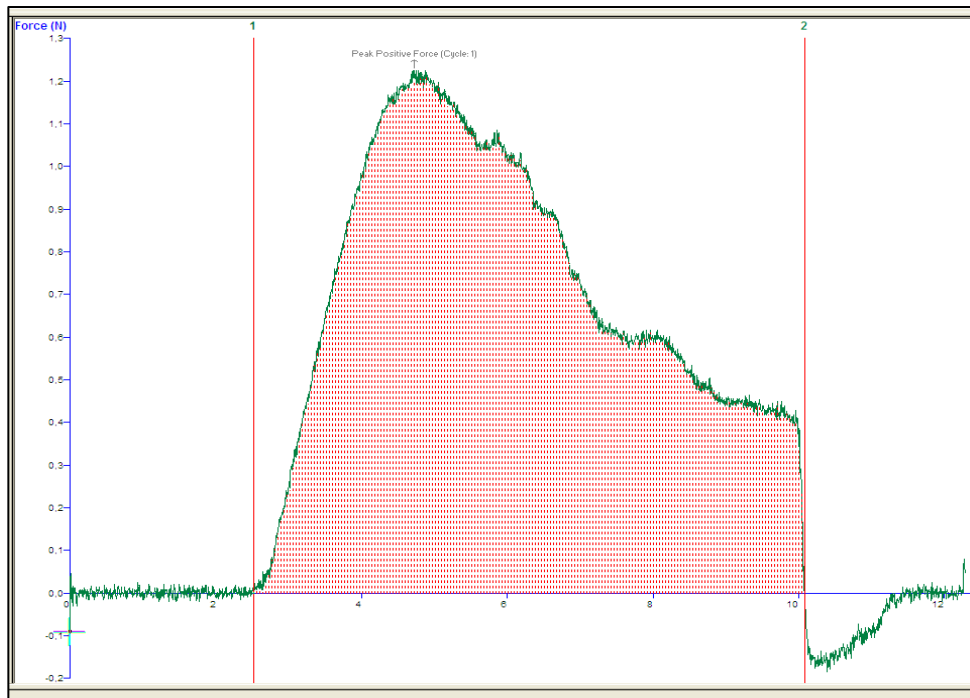
A transparent film individually covered the provided samples. The samples were then measured after the heat treatment procedure using a CR-400 chromameter (Konica Minolta Co., Japan) at room temperature. Three replications were carried out for each sample to ensure precision. The CIE-LAB elements were defined, and the colour factors of L^* , a^* , and b^* were identified within the homogeneous colour space CIE-LAB. Positive values of a^* indicated reddish colours while negative values indicated greenish hues. Positive values of b^* corresponded to yellowish hues, and negative values indicated bluish colours. The L^* value ranged from 0 to 100 and indicated the lightness of the sample.

4.2.4 Rheological parameters measurement

After cooling, the prepared samples were tested for rheological parameters. Each patty sample was placed on a stand, and six repetitions were performed on each one. The test type used was a “puncture” test, in which a cylindrical probe penetrated the patty sample. To investigate the rheological properties, a TA.XT Plus texture analyser was employed. The analyser was fitted with a 5 mm stainless steel cylindrical probe (P/5). The settings applied included: test mode – compression; pre-test and test speed – 2 mm/sec; post-test speed – 10 mm/sec. The target mode was set to “distance,” with a target distance of 20 mm, and a minimum trigger force of 0.049 N. The device was operated using TA.XT texture analyser software, and all measurements were conducted at a constant temperature of 20 °C. For result evaluation, two main parameters were selected as indicators of overall texture: the peak positive piercing force (measured in N) and the adhesive working area (positive, measured in N·mm).

Figure 2.1. provides an example of the adhesive work area, demonstrating how this data was measured and collected. The graph in *Figure 2.1.* shows the 40/60 mixture in the 4th repetition. Only the positive work area was measured, as the negative work area represents the relaxation stage of the measurement.

Figure 2.1 Positive work area graph example



4.2.5 Statistical analyses

To assess the influence of sample composition and heat treatment method on texture parameters, a repeated measures ANOVA test was conducted. This statistical approach was chosen because each patty sample underwent multiple testing conditions, allowing for the analysis of within-subject variability. The repeated measures design ensured that the influence of individual sample differences was minimised, improving the reliability of the comparisons across treatments. The analysis focused on two primary rheological parameters obtained from the piercing test: peak positive piercing force (N) and adhesive work area (N·mm). Each measurement was performed in six replicates per sample. For each treatment group, mean values and standard deviations were calculated, and the assumptions of normality and sphericity were verified prior to analysis.

Statistical analysis was carried out using Past 4, where significance was evaluated at a 95% confidence level ($p < 0.05$). Where significant effects were found, post hoc pairwise comparisons with Bonferroni correction were applied to identify specific differences between the groups.

IBM SPSS software (Version 29, SPSS Inc., Chicago, IL, USA) for macOS was used to perform analysis of variance. Tukey's post hoc test was performed to detect significant differences between groups. Multivariate statistical methods were also used to evaluate the

results: Principal Component Analysis (PCA) and Canonical Discriminant Analysis (CDA). The PCA, a non-supervised method, is based on extracting substantial information (capturing the maximum amount of variance) with dimension reduction to detect similarities of the samples. The CDA is a supervised method that tries to maximally separate the different groups by focusing on the ratio between class variance and within-class variance. Levels for significant differences were set at $p < 0.05$ in all cases.

4.2.6 Visual shrinkage measurement

For the visual shrinkage measurement, images of the meat patty samples were captured both before and after heat treatment. To ensure precision and consistency, the camera was positioned at a fixed height and angle relative to the table surface. Each sample was tested once, with three parallel patties analysed per formulation.

Figure 2.2 Representative picture of the visual shrinkage measurement process



A GoPro camera was used for image acquisition. A measurement ruler was included in each image to allow for accurate scaling during analysis. Visual shrinkage was determined by comparing the surface area of each patty before and after thermal processing. The following formulas were applied to calculate the shrinkage percentage:

$$\text{Conversion equation: } 1 \text{ (mm)} = \frac{l_{10}}{100} = y \text{ (pixels)}$$

Where:

l_{10} : the average number of pixels on a 10 cm section of a ruler

$$\text{Visual shrinkage (\%)} = \frac{\frac{x1}{y} - \frac{x2}{y}}{\frac{x1}{y}} \cdot 100\%$$

Where:

x1: the number of pixels on a patty diameter before heat treatment

x2: the number of pixels on a patty diameter after heat treatment

y: number of pixels in 1 mm

4.2.7 Sensory analysis measurement

For the sensory analysis, a Quantitative Descriptive Analysis (QDA) combined with elements of a hedonic test and projective mapping test was conducted involving 27 panellists. Each sample was coded with a random two-digit number, and a total of 22 samples were evaluated, including those prepared using grilling and oven baking heat treatment methods. The panellists assessed four key sensory attributes: smell, taste, overall acceptability, and the perceived character of the sample (i.e., whether it was more meat-like or mushroom-like).

For the attributes of smell, taste, and overall acceptability, a hedonic scale ranging from 0 to 10 was used, where 0 indicated “disgusting” and 10 represented “very pleasant.” To evaluate the perceived character of the sample, a separate scale from 0 to 20 was used: 0 indicated a strong mushroom-like character, 20 indicated a strong meat-like character, and 10 represented a neutral balance.

At the beginning of the test, all panellists were blinded to the composition of the samples, and the order of sample presentation was randomised to prevent bias. Each sample was served in 10 g portions, and panellists were instructed not to add salt or sauces to ensure consistent and fair evaluation. All panellists were regular meat consumers who expressed an interest in healthier food products, provided they did not have to alter their dietary habits significantly.

5. Results and Discussions

5.1 Yield measurement of meat-reduced mushroom-based burger patty samples

As seen in *Figure 3.* and *Figure 4.* the final product after certain types of cooking has some losses, mainly due to moisture loss.

Figure 3. Yield parameters of grilled meat-mushroom patty samples. a-e: Distinct letters indicate significant differences among the samples. (Tukey's post hoc test, $p < 0.05$).

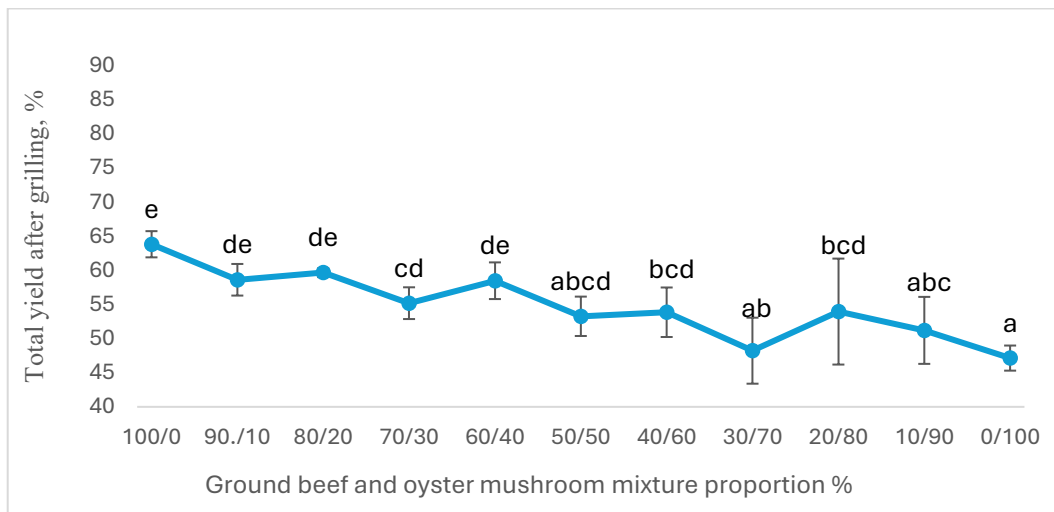


Figure 4. Yield parameters of oven-baked meat-mushroom patty samples. w-z: Distinct letters indicate significant differences among the samples. (Tukey's post hoc test, $p < 0.05$).

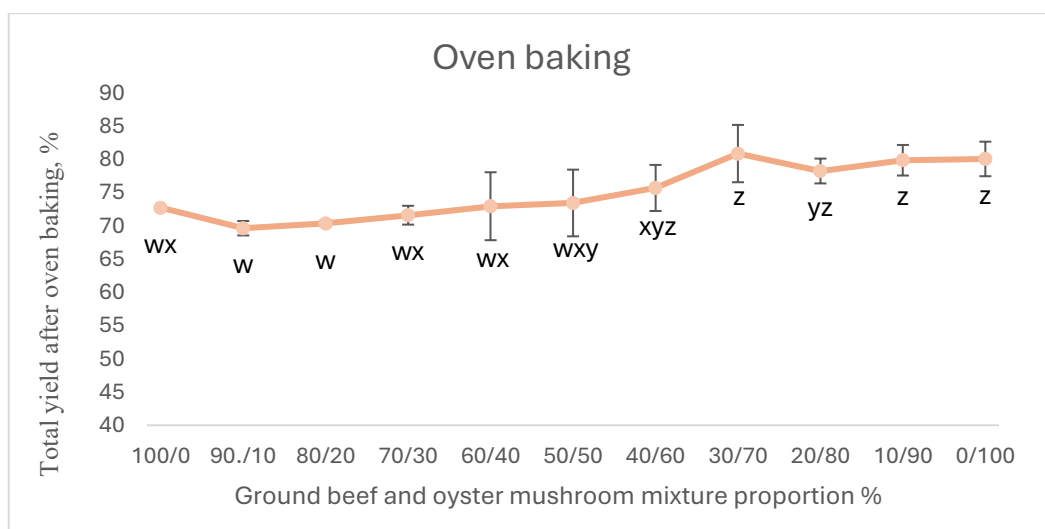


Figure 3. depicts yield after grill-type cooking, and *Figure 4.* depicts oven-baked type of cooking. 100/0, 90/10, etc., represent how much ground beef and how much oyster

mushroom the mixture contains. The 1st number represents ground beef percentage, and the 2nd number represents oyster mushroom percentage. The letters a, b, c, d, e and w, x, y, z and their combinations were used as label notations to indicate group membership in homogeneous subsets, reflecting both the differences and overlapping belonging among the sample groups.

A clear pattern is evident in *Figure 3*. The more oyster mushrooms the mixture contains, the more moisture the grilling method evaporates. The maximum value in the grill case can be seen with the 100/0 ratio, where the yield is 63.81 g, and the lowest can be seen in the case of 0/100, where the yield is 47.14 g. Similar results can be seen in the study by Pathare and Roskilly (2016), which confirms that direct dry-heat cooking, such as grilling, tends to cause higher water and fat loss, especially in plant-based or high-moisture content ingredients like mushrooms. This suggests that grilling may not be the optimal method for achieving optimal moisture retention, particularly in mushroom-enriched formulations (Pathare & Roskilly, 2016).

In *Figure 4*, we can see oven-baked samples. There, a clear opposite pattern may be observed. The more mushroom content, the more moisture is retained in the final product. Processing errors, such as uneven heat flow inside the oven, should still be considered. However, this method preserves more moisture and might be helpful for specific procedures in the food industry. The highest value in *Figure 4* can be seen in the 30/70 mixture, where the yield is 80.89 g, and the lowest value is observed in the 90/10 mix, where the yield is 69.65 g. Similar results are reported in Bakhsh et al. (2021), who found that oven baking yields lower cooking loss and higher water-holding capacity compared to dry-heat methods. This suggests that oven baking could be more suitable for producing juicy, high-yield meat alternatives containing mushrooms (Bakhsh et al., 2021).

5.2 Colour measurement of meat-reduced mushroom-based burger patty samples

On *Figure 5*., *Figure 6*., and *Figure 7*., colour parameter results can be observed. 100/0, 90/10, etc., represent how much ground beef and how much oyster mushroom the mixture contains. The 1st number represents ground beef percentage, and the 2nd number represents oyster mushroom percentage. The letters y, z; a, b; a, b, c; z; and a, b, c, d, e and their

combinations were used as label notations to indicate group membership in homogeneous subsets, reflecting both the differences and overlapping belonging among the sample groups. The L^* parameter in *Figure 5*. represents lightness (from 0 = black to 100 = white), a^* in *Figure 6*. indicates redness (+127) to greenness (-128), and b^* in *Figure 7*. describes yellowness (+127) to blueness (-128). The Lab^* system is described in ISO 11664-4:2008 (CIE 1976) and is commonly used for measuring food colour in both research and industrial applications due to its objectivity and reproducibility.

Figure 5. L^* colour results of the measured meat-mushroom sample mixtures. y-z: Distinct letters indicate significant differences among the oven-baked samples. a-b: Distinct letters indicate significant differences among the grilled samples. (Tukey's post hoc test, $p < 0.05$).

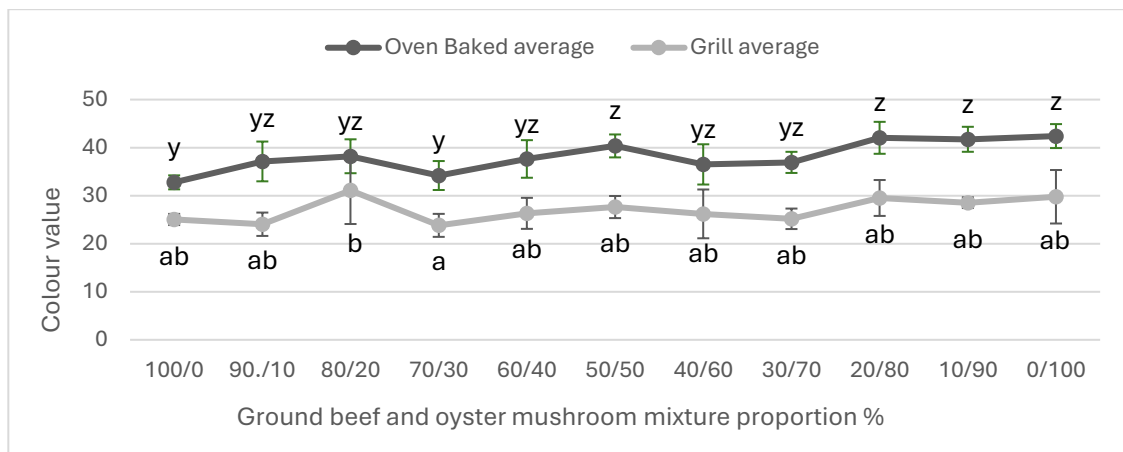


Figure 6. a^* colour results of the measured meat-mushroom sample mixtures. a-c: Distinct letters indicate significant differences among the grilled samples. (Tukey's post hoc test, $p < 0.05$).

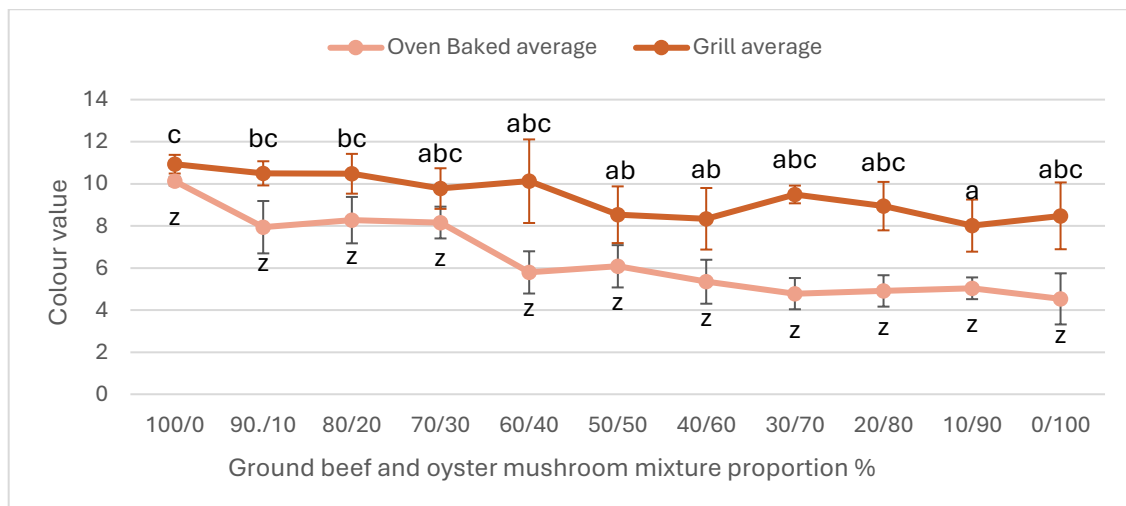
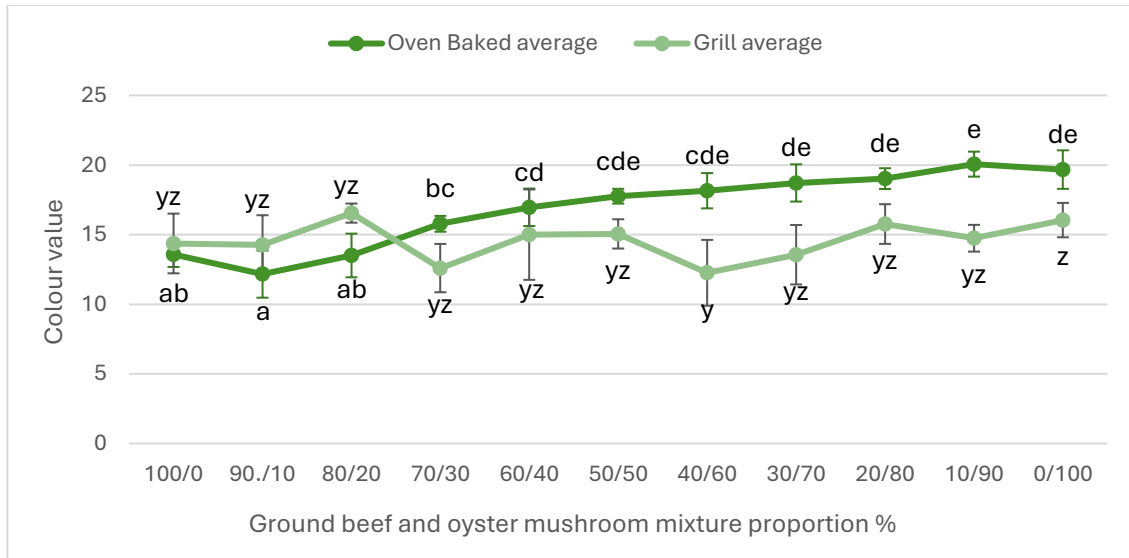


Figure 7. *b** colour results of the measured meat-mushroom sample mixtures. y-z: Distinct letters indicate significant differences among the grilled samples. a-e: Distinct letters indicate significant differences among the oven-baked samples. (Tukey's post hoc test, $p < 0.05$).



In *Figure 5*, two legends represent oven-baked and grilled samples. A visible trend may be seen: the more mushroom content the sample contains, the higher its lightness value L^* . Oven-baked: The highest value is seen in the 0/100 mix, where L^* is 42.4, showing moderate sample lightness. The lowest value is in the 100/0 mix, with L^* of 32.77, indicating a relatively dark sample. Grill mixtures: the highest L^* value appears in the 80/20 mix (31.1), while the lowest is in the 70/30 mix (23.81). In the oven-baked group, lightness values are more stable and gradually increase with mushroom content, likely due to less browning and the intrinsic light colour of oyster mushrooms. Similar findings can be described in the study by Serdaroglu et al. (2017), which indicates that increased plant-based ingredients in meat analogues lead to lighter product colour, especially when cooked with low surface exposure methods like baking (Serdaroglu et al., 2017).

In *Figure 6*, where the a^* values are represented, another pattern emerges. The more mushroom content, the lower the a^* value, which aligns with the known colour characteristics of raw ingredients—meat typically has reddish tones. In contrast, oyster mushrooms are more neutral to greyish-greenish in hue. Oven-baked mixtures: the highest a^* value is 10.125 (100/0), and the lowest is 4.531 (0/100). Grill mixtures: the highest is 10.93 (100/0), the lowest is 8.01 (10/90). In both cooking types, the trend is the same;

however, the grill samples show a more defined trend, likely due to surface browning and crust formation enhancing red-brown tones. Similar findings can be found in Fernández-Ginés et al. (2003), which indicate that surface browning during high-heat methods enhances redness (a^*), especially in samples with higher meat content (Fernández-Ginés et al., 2003).

In *Figure 7*, b^* values are presented. For oven-baked samples, a clear pattern is observed: more mushroom content corresponds to higher b^* values, indicating increasing yellowness. The highest value is in the 10/90 mix (20.06), and the lowest is in the 90/10 mix (12.165). This trend likely results from the natural yellowish hue of mushrooms becoming more dominant as their proportion increases, combined with less Maillard browning than in grilling. In the grill group, no consistent trendline is seen, and b^* values are relatively stable. The highest value is in the 80/20 mix (16.545), and the lowest is in the 40/60 mix (12.25). This could be due to the grilling process inducing uneven surface browning, affecting the colour heterogeneity. Similar findings can be seen in studies such as García-Segovia et al., (2007), which indicate that cooking method and formulation both affect b^* values. However, grill-induced crust development can mask the underlying colour changes caused by ingredient ratios (García-Segovia et al., 2007).

5.3 Rheological parameters measurement of meat-reduced mushroom-based burger patty samples

Figure 8. and *Figure 9.* illustrate the rheological parameters of the mixture samples measured using the TA.XT texture analyser. The objective of these measurements was to assess the maximum piercing force applied in Newtons (*Figure 8.*) and adhesive work area in Newtons*mm (*Figure 9.*). The notations such as 100/0, 90/10, etc., represent the composition of ground beef and oyster mushrooms in the mixture. The first number indicates the percentage of ground beef, and the second number indicates the percentage of oyster mushrooms. The letters a, b, c, d, e; x, y, z and 1, 2, 3, 4 and their combinations were used as label notations to indicate group membership in homogeneous subsets, reflecting both the differences and overlapping belonging among the sample groups. The two trendlines represent different cooking methods, as detailed in the figure legend.

Figure 8. The maximum piercing force applied to the meat-mushroom sample mixtures. *x-z*: Distinct letters indicate significant differences among the grilled samples. *a-e*: Distinct letters indicate significant differences among the oven-baked samples. (Tukey's post hoc test, $p < 0.05$).

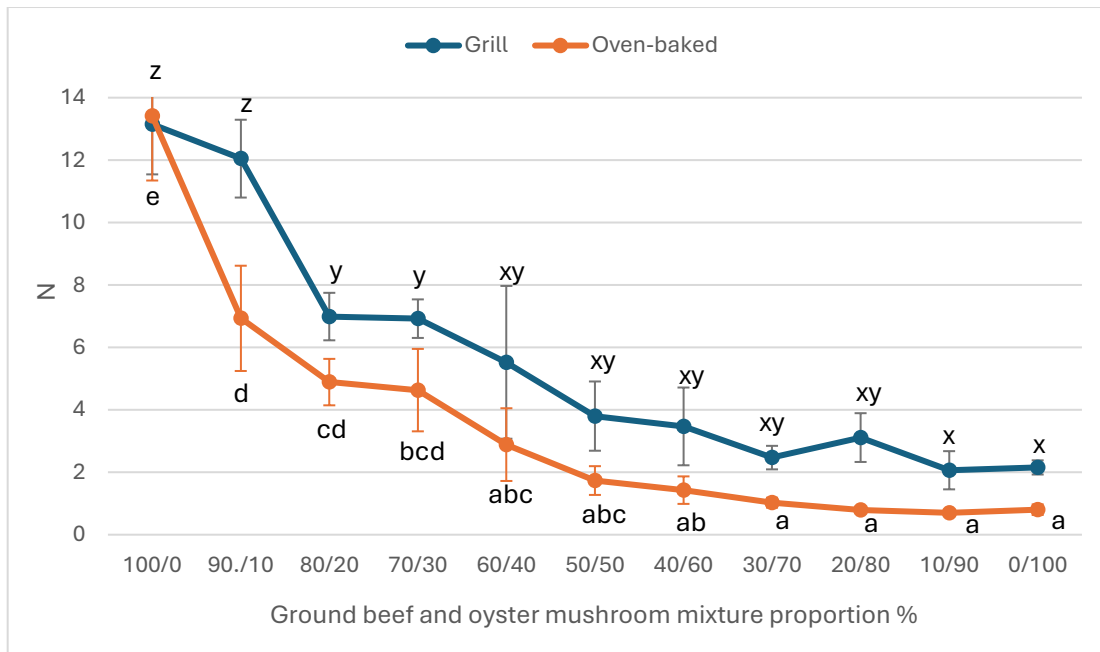


Figure 9. Positive work area results of the meat-mushroom sample mixtures. *1-4*: Distinct letters indicate significant differences among the grilled samples. *a-e*: Distinct letters indicate significant differences among the oven-baked samples. (Tukey's post hoc test, $p < 0.05$).

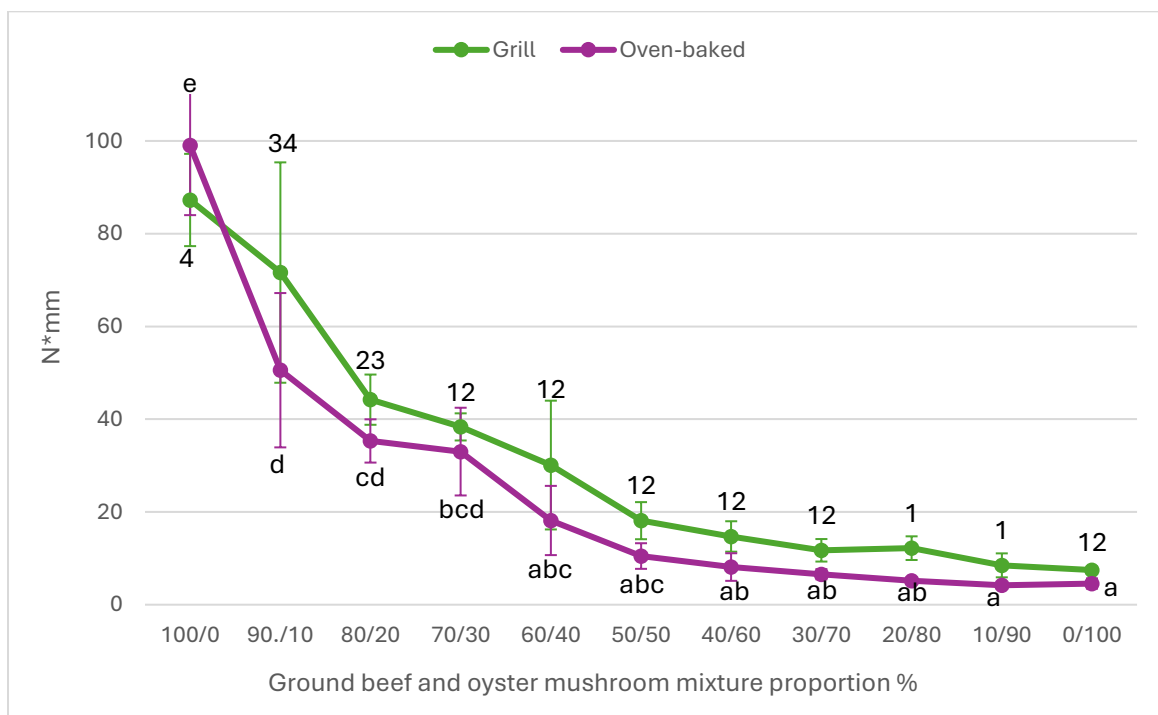


Figure 8. displays a non-linear (parabolic) decreasing trendline. As the proportion of mushrooms in the mixture increases, the maximum piercing force applied decreases. This suggests that the hardness and endurance of mushrooms are lower than that of meat. As the meat content decreases in the mixture, the overall texture and resistance become softer, likely due to the structural differences between meat and mushrooms. This explanation is supported by the fact that mushrooms have a softer and more porous structure compared to the denser and more rigid structure of ground beef (Arun et al., 2021). In case of the grilling method, the highest value was found in the 100/0 mix, with 13.149 N, while the lowest value occurred in the 10/90 mix, at 2.0648 N. Several large standard deviations were observed in the 100/0 and 40/60 mixes, indicating either non-homogeneous distribution or possible measurement error. In case of the oven baking method, the highest value was recorded in the 100/0 mix at 13.416 N, while the lowest value was in the 10/90 mix, at just 0.701 N. The only significant standard deviation was found in the 100/0 mix, with a value of 2.0699. This could be attributed to the structure of ground beef, which may lead to greater variability in the results. These findings suggest that the texture of the ground beef portion of the mixture has a greater impact on the overall texture than the oyster mushrooms, which exhibit more uniformity across different mixtures (Bakhsh et al., 2021).

In *Figure 9.* similar observations can be made. The adhesive work area follows a similar parabolic decreasing trend, indicating that as the mushroom content increases, the adhesive work decreases. This suggests that the structural differences between meat and mushrooms are influencing the rheological properties. As previously mentioned, the texture profile becomes softer and smoother as the mushroom content increases, which is consistent with the observed reduction in adhesive work. In the case of the grilling method, the highest value of adhesive work (87.268 N*mm) was found in the 100/0 mix, while the lowest value (7.47 N*mm) was in the 0/100 mix. The highest standard deviation was observed in the 90/10 mix, with a value of 23.76, indicating significant variation in the texture of that mixture. In case of oven baking method, the highest value was found in the 100/0 mix, at 99.027 *mm. Interestingly, the 90/10 mix already had a value of 50.56 N*mm, which is nearly a 50% decrease from the 100/0 mix, indicating that the mushroom significantly influences the texture profile. The lowest value was recorded in the 10/90 mix at 4.19 N*mm. High standard deviations were also observed in mixtures with higher meat content, further supporting the idea that the meat structure introduces more variability in texture. These observations are consistent with the literature on the structural properties of meat and mushrooms, which

indicate that the former has a denser, more fibrous structure, while mushrooms tend to be more porous and softer (Arun et al., 2021).

5.4 Statistical analyses on parameters of meat-reduced mushroom-based burger patty samples

In *Figure 10.1* the discrimination of samples based on heat treatment is illustrated using REGR factor scores. The data points on the graph represent various parameters, including yield, $L^*a^*b^*$ colour values, visual shrinkage, and rheological properties. Each point corresponds to a specific sample, allowing for a comparative analysis of these parameters. The samples are distinctly grouped according to the type of heat treatment applied—either oven-baked or grilled. This grouping pattern, with only minor deviations among points, indicates that the measured parameters differ significantly between the two heat treatment methods. This method is commonly applied in food science research to assess how different processing techniques simultaneously influence multiple quality attributes. For example, REGR factor analysis has been successfully employed by Wyrwisz et al. (2012) to assess the impact of thermal treatment on meat texture and colour, making it a suitable approach for the present study as well (Wyrwisz et al., 2012).

Figure 10.1 Discriminant analysis of meat-mushroom samples based on heat treatment using REGR factor scores

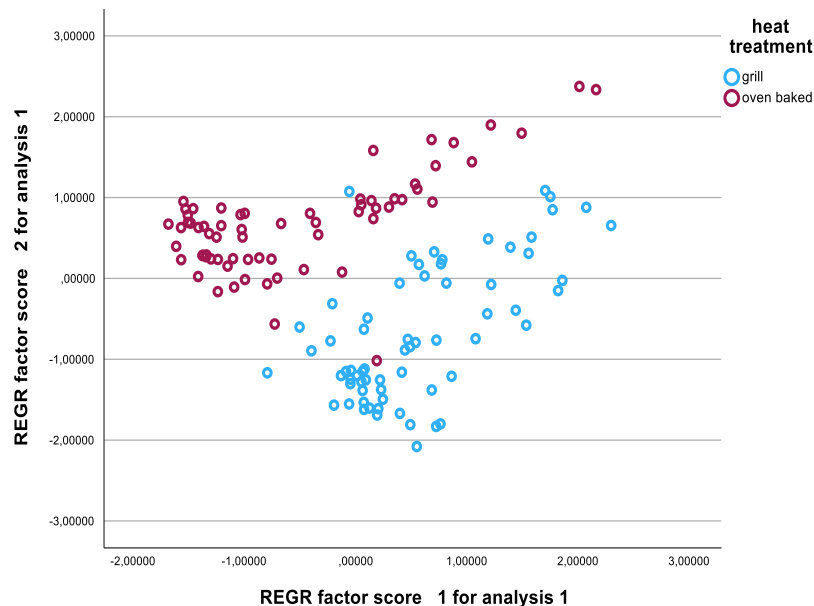


Figure 10.2 Canonical discriminant analysis (CDA) of grilled meat–mushroom mixtures

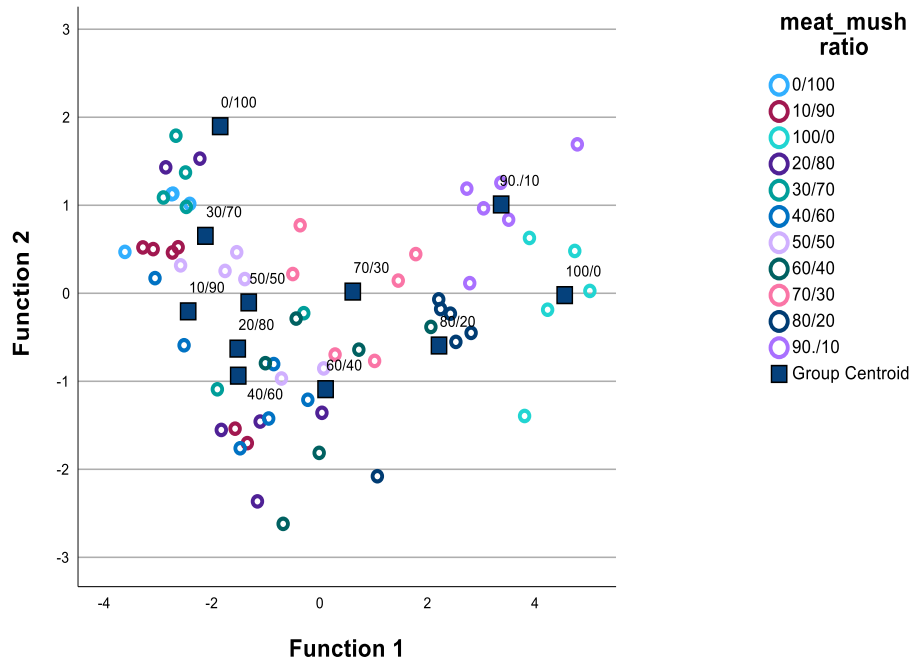
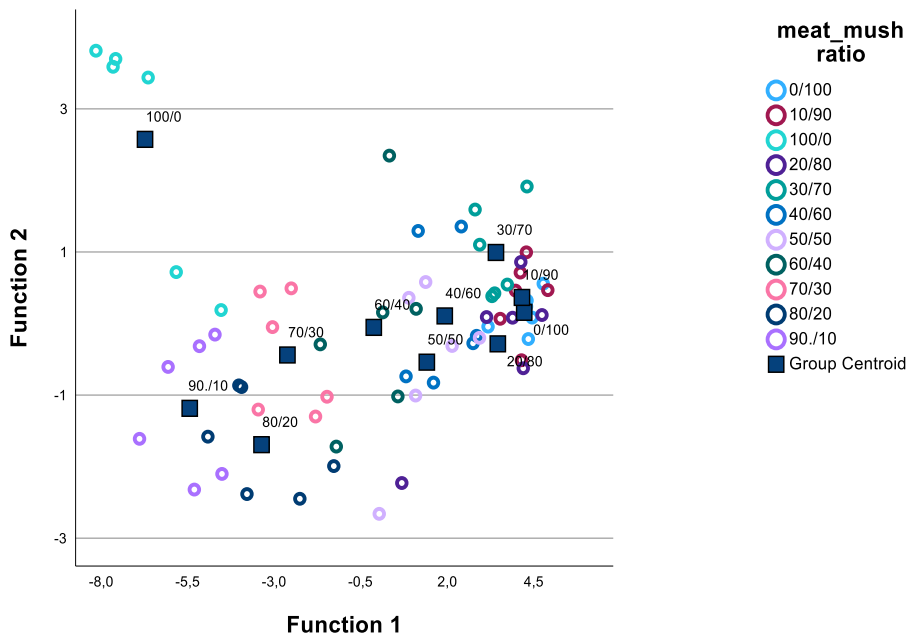


Figure 10.3 Canonical discriminant analysis (CDA) of oven-baked meat–mushroom mixtures



In *Figure 10.2* the canonical discriminant analysis (CDA) of grilled meat–mushroom mixtures is presented, while *Figure 10.3* illustrates the CDA of oven-baked meat–mushroom mixtures. The notations such as 100/0, 90/10, etc., denote the composition of ground beef

and oyster mushrooms in the mixture, with the first number indicating the percentage of ground beef and the second representing the percentage of oyster mushrooms. Both graphs compare data on yield, $L^*a^*b^*$ colour values, rheological parameters, and visual shrinkage. Squares on the graphs represent the average positioning according to the canonical discriminant of each group mixture, allowing for the visualisation of overall differences between sample groups. According to the SPSS statistical analysis of the grilled samples, 66.7% of the original grouped cases were correctly classified. Cross-validation, performed by classifying each case using functions derived from all other cases, resulted in 42.4% of cross-validated grouped cases being correctly classified. For the oven-baked samples, 53.0% of the original grouped cases were correctly classified, with cross-validation yielding a 33.3% correct classification rate. These results suggest that while the grouping was not significantly accurate, there is still a discernible differentiation between the groups.

In *Figure 10.2* most groups are centred with a particular pattern, though some group deviations are evident. Notably, the 0/100 group is positioned higher than the majority of samples, indicating a significant difference. Additionally, deviations are observed in the 90/10 and 100/0 groups, which are placed further to the right, suggesting that high mushroom content significantly influences the parameters of meat-reduced, mushroom-based patty samples (Ilaria et al., 2021).

Figure 10.3 illustrates a closer clustering of sample placements, indicating overall similarity in the results. However, the 100/0 group is positioned well above the majority, suggesting that in oven-baked samples, the 100% meat patty parameters are unique and cannot be grouped with mushroom-based analogues. The 90/10 and 80/20 groups are located to the left and below the majority, indicating their significant difference and lack of similarity with samples containing higher mushroom ratios. Similar findings have been reported in studies where canonical discriminant analysis was applied to assess the effects of meat substitution with oyster mushrooms on the quality characteristics of sausages. These studies utilised CDA to distinguish between different formulations based on physicochemical and sensory properties, demonstrating the method's effectiveness in differentiating sample groups based on compositional variations (Ilaria et al., 2021).

Additionally, Tukey's post hoc test on homogeneous subsets was performed to detect significant differences between the mixture groups with varying meat-mushroom content. This analysis was applied to *Figure 3.* and *Figure 4.* for group comparisons of

yield; *Figure 5.*, *Figure 6.*, and *Figure 7.* for colour values; *Figure 8.* and *Figure 9.* for rheological parameters; and *Table 2.* for visual shrinkage measurements. The notations used in these figures and tables indicate group memberships, with some groups assigned multiple letters or numbers (e.g., ab, abc, abcde, xyz, wxyz, 1234, yz) to reflect their inclusion in multiple homogeneous subsets. This method, as described by Ilaria et al. (2021), is commonly employed in food science research to identify statistically significant differences among sample groups based on various quality parameters (Ilaria et al., 2021).

5.5 Visual shrinkage measurement of meat-reduced mushroom-based burger patty samples

Table 2. presents the results of visual shrinkage measurements, showing shrinkage percentages based on diameter changes measured in millimetres. The notations, such as 100/0, 90/10, etc., represent the composition of ground beef and oyster mushrooms in the mixture. The first number indicates the percentage of ground beef, and the second number represents the percentage of oyster mushrooms. The letters a, b, c, and y, z and their combinations were used as label notations to indicate group membership in homogeneous subsets, reflecting both the differences and overlapping belonging among the sample groups.

Table 2. Visual shrinkage results of the burger patty meat-mushroom sample mixtures. a-c: Distinct letters indicate significant differences among the grilled samples. y-z: Distinct letters indicate significant differences among the oven-baked samples. (Tukey's post hoc test, $p < 0.05$).

Grill samples mixture type	Shrinkage (%) Average and Standard Deviation	Oven samples mixture type	Shrinkage (%) Average and Standard Deviation
100/0	15,05 ^c ± 5,09	100/0	21,63 ^z ± 1,97
90/10	13,57 ^{bc} ± 4,30	90/10	20,69 ^z ± 2,12
80/20	15,94 ^c ± 2,19	80/20	17,82 ^z ± 4,26
70/30	10,53 ^{abc} ± 4,61	70/30	17,74 ^z ± 3,16
60/40	6,33 ^a ± 4,96	60/40	9,42 ^y ± 3,31
50/50	7,70 ^{ab} ± 1,48	50/50	8,13 ^y ± 2,77

40/60	$7,92^{ab} \pm 2,92$	40/60	$7,96^y \pm 2,00$
30/70	$7,24^{ab} \pm 2,26$	30/70	$8,64^y \pm 3,21$
20/80	$6,70^a \pm 2,02$	20/80	$8,76^y \pm 3,40$
10/90	$7,01^a \pm 1,69$	10/90	$8,63^y \pm 1,47$
0/100	$6,49^a \pm 2,16$	0/100	$8,48^y \pm 1,47$

Visual shrinkage measurement provides insights into the overall appearance after cooking, as well as the objective influence of the meat-mushroom content on yield.

Table 2. shows similar results to those observed in yield measurements (*Figure 3.* and *Figure 4.*) as these two parameters are correlated. Shrinkage is generally associated with water loss and changes in texture after cooking, which directly affects yield. As the mushroom content increases, the mixture tends to retain more moisture, resulting in less shrinkage. This suggests that the more porous structure of mushrooms may help retain moisture compared to the denser structure of meat, which tends to shrink more as it loses water during cooking. Findings from Dikeman et al. (2005) support this observation, indicating that higher mushroom content leads to lower shrinkage due to the increased water-holding capacity of mushrooms (Dikeman et al., 2005).

In the case of the grilling method, the highest shrinkage percentage (15.057%) is observed in the 100/0 mix, while the lowest shrinkage percentage (6.49%) is seen in the 0/100 mix. High standard deviations are primarily found in meat-enriched mixtures. For example, the 100/0 mix has a standard deviation of 5.09, indicating considerable variability in shrinkage within that mixture. This could be due to the inherent variability in the meat's structure, which results in more inconsistent shrinkage during grilling. In the oven-baking method, the maximum shrinkage is observed in the 100/0 mix, with a shrinkage percentage of 21.635%. The minimum shrinkage in this method occurs in the 10/90 mix, with a shrinkage percentage of 8.63%. Standard deviations in oven baking results are accidental and do not follow a clear pattern, which may be attributed to inconsistencies in heat distribution during the baking process. This unpredictability suggests that oven-baking might introduce more variability in shrinkage due to uneven heat flow within the oven (Zhuang & Savage, 2008).

Additionally, in comparison, the shrinkage percentage is higher in oven baking than in grilling. This difference can be attributed to the higher temperatures used in oven baking, which may cause greater water loss and texture contraction in meat compared to grilling. Grilling typically involves direct heat, which may reduce moisture loss more effectively by searing the surface and sealing in moisture (Mazumder et al., 2023). Similar results were found by Zhuang & Savage (2011), who reported that moisture retention during oven baking was lower than grilling due to the prolonged exposure to heat (Mazumder et al., 2023; Zhuang & Savage, 2011).

5.6 Sensory analysis measurement of meat-reduced mushroom-based burger patty samples

Figure 11. and Figure 12. present the results obtained from sensory analyses. The notations, such as 100/0, 90/10, etc., represent the composition of ground beef and oyster mushrooms in the mixture. The first number indicates the percentage of ground beef, and the second number represents the percentage of oyster mushrooms. In the first half of both figures, we observe evaluations of smell, taste, and overall liking on a scale from 1 to 10, where 1 denotes "disgusting" and 10 signifies "excellent." The second half illustrates participants' perceptions of whether the meat patty sample had meat-like characteristics (score of 20) or mushroom-like characteristics (score of 0). A score of 10 represents a neutral character, indicating that the participant could not discern whether the sample was more meat- or mushroom-like. All participants followed a meat-based diet.

Figure 11. Sensory evaluation results of oven-baked patty sample mixtures

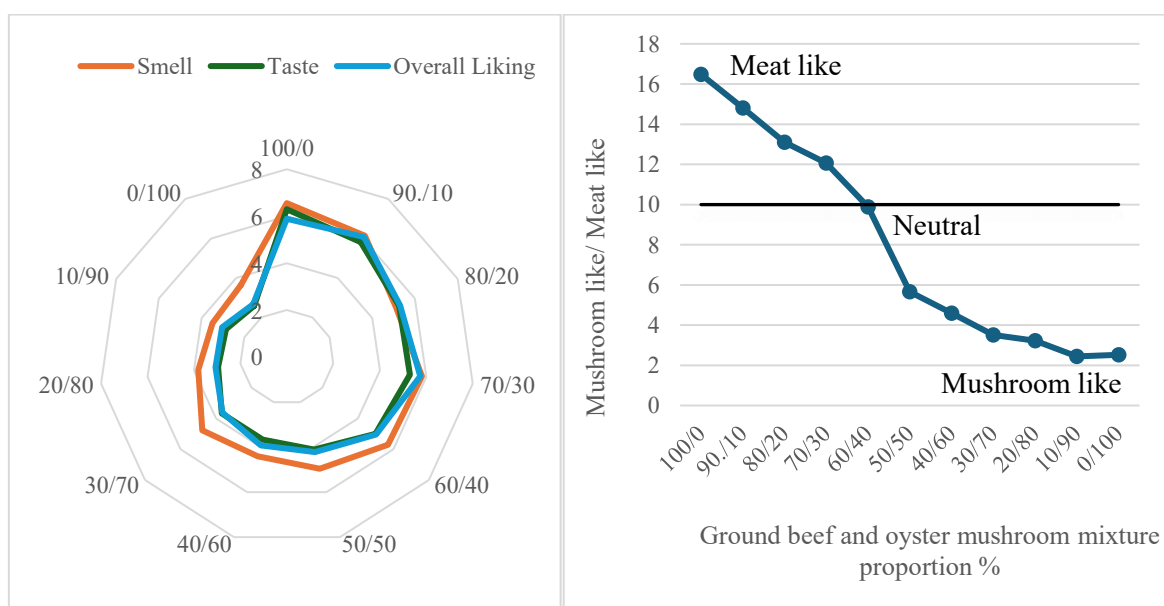


Figure 12. Sensory evaluation results of grilled meat-mushroom sample mixtures

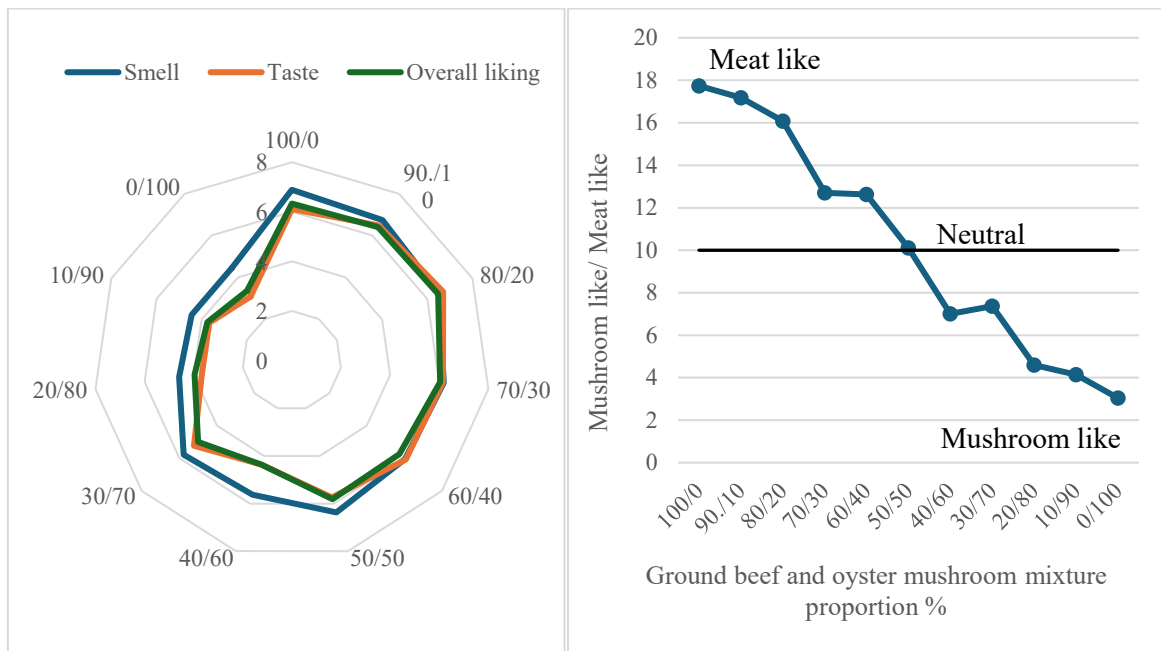


Figure 11. represents the sensory evaluation of oven-baked samples. In the first half, the highest scores are observed in samples ranging from the 100/0 mix to the 60/40 mix. These mixtures received the most favourable evaluations on average. Specifically, the 100/0 mix achieved the highest scores for smell (6.55) and taste (6.29), while the 90/10 mix received the highest overall liking score (6.07). The 80/20 mix scored 5.11 for smell, 5.25 for taste, and 5.29 for overall liking. The 70/30 mix obtained scores of 5.81 for smell, 5.29 for taste, and 5.74 for overall liking. The 60/40 mix received 5.70 for smell, 5.00 for taste, and 5.03 for overall liking. Notably, while the 100/0 mix had the highest smell and taste scores, the 90/10 mix achieved the highest overall liking score. This suggests that a slight inclusion of oyster mushrooms may enhance the meat's sensory properties without significantly altering its character. Similar observations were reported by Sogari et al. (2023), who found that hybrid meat-mushroom burgers were well-received by consumers, indicating that mushroom inclusion can positively influence sensory attributes without compromising meat-like qualities. Scores significantly declined beyond the 60/40 mix in oven-baked samples. Participants indicated that mixtures exceeding this ratio resulted in a dominant oyster mushroom taste and smell, which were not pleasant to them. The lowest scores were observed in the 0/100 mix, with smell at 3.62, taste at 2.59, and overall liking at 2.66. These findings align with those of Sogari et al. (2023), who noted that higher levels of plant-based ingredients in meat analogues could negatively impact consumer acceptance (Sogari et al., 2023).

In the second half of *Figure 11*, we examine the meat/mushroom characteristic perceptions of oven-baked samples. The 100/0 mix received a score of 16.48, indicating a dominant meat flavour. However, this score is below the expected 20, which could be attributed to factors such as cross-sample aroma contamination or participants' anticipation of mushroom presence, given that they were unaware of the specific mixture ratios. Similar to the first half, meat flavour dominance persisted up to the 60/40 mix, where the score was 9.888, suggesting a neutral perception. Beyond this ratio, the oyster mushroom flavour became more prominent. The most mushroom-like sample, the 10/90 mix, received a score of 2.444. These results are consistent with findings by Sogari et al. (2023), who reported that higher proportions of plant-based ingredients in hybrid products led to increased perception of non-meat flavours, affecting overall consumer acceptance (Sogari et al., 2023).

Figure 12 presents the sensory evaluation results for grilled samples. As in *Figure 11*, the first half of the figure displays results for smell, taste, and overall liking rated on a 10-point scale. The second half measures participants' perception of meat-like or mushroom-like characteristics, ranging from 0 (completely mushroom-like) to 20 (completely meat-like), with 10 indicating neutrality. The results of the grilled samples follow a similar trend to the oven-baked ones. The highest scores were observed in samples ranging from the 100/0 to 50/50 mixtures. Specifically, the 100/0 mix had the highest score for smell (6.88), taste (6.11), and a high overall liking score of 6.33. The 90/10 mix achieved smell – 6.74, taste – 6.48, and overall liking – 6.4. The 80/20 mixture yielded smell – 6.51, taste – 6.70 (the highest among all), and overall liking – 6.48 (also the highest among all grilled samples). The 70/30 mix followed with smell – 6.18, taste – 6.14, and overall liking – 6.03. The 60/40 mix achieved smell – 6.04, taste – 6.07, and overall liking – 5.74. Lastly, the 50/50 sample had a smell score of 6.37, taste – 5.74, and overall liking – 5.81. These results suggest that a small proportion of oyster mushrooms, particularly around the 20% mark, may enhance the sensory attributes of the meat patty without overpowering the meat character. Similar findings were reported by Yuan et al. (2021), who demonstrated that the incorporation of edible mushrooms in meat products improved flavour complexity and overall palatability when used in moderation (Yuan et al., 2021).

The second half of *Figure 12* illustrates participants' perception of meat versus mushroom-like character in grilled patties. The highest value was observed in the 100/0 sample (17.74), suggesting that in grilled samples, participants more clearly identified the presence of meat

compared to oven-baked ones. The 90/10 sample followed closely with a score of 17.185, indicating that at this ratio, the presence of mushrooms was hardly perceptible to meat-eating participants. After the 90/10 mix, the scores decreased proportionally, suggesting increasing mushroom dominance. The neutral perception point (score ~10) was reached at the 40/60 mixture. The most mushroom-like result was observed in the 0/100 mix, which received a score of 3.04. These findings are consistent with those reported by Michel et al. (2021), who found that hybrid products with over 50% plant content are more likely to be perceived as "non-meat" by omnivorous consumers, potentially reducing their acceptability (Michel et al., 2021).

A comparative analysis of *Figure 11.* and *Figure 12.* suggests that overall liking scores were generally higher for grilled samples. This could be attributed to the formation of a pleasant crust during grilling, which adds desirable texture and flavour complexity. As noted by Chen and Rosenthal (2015), Maillard reactions occurring during grilling can enhance the aroma and taste profile, making grilled patties more appealing to consumers.

Additionally, mushroom flavour dominance was more pronounced at higher inclusion levels in grilled samples than in oven-baked ones. This may be due to partial masking of the mushroom aroma by the grilled meat's enhanced flavour and aroma intensity. Similar findings were discussed by Ismail et al. (2020), who found that cooking methods involving direct dry heat (e.g., grilling) intensify umami compounds and may reduce off-notes from plant-based ingredients in hybrid formulations (Ismail et al., 2020).

5.7 Summary of the results

Overall, some clear patterns can be seen in the discovered results. In the case of the yield study, we observed that by reducing the meat content during grilling, the yield also decreased. However, when using cooking (oven baking), the same procedure resulted in increased yield due to the higher moisture retention of the oyster mushroom product (Pathare & Roskilly, 2015; Bakhsh et al., 2021).

For colour measurement, a clear pattern was also observed. Regarding the L* (lightness) value, the values differed between grilling and cooking but remained stable during the reduction of meat content. This indicates that increased plant-based ingredients in meat

analogues lead to a lighter product colour, especially when cooked with low surface exposure methods like baking (Serdaroglu et al., 2017).

In the case of the a^* value, for both cooking methods, the values slowly decreased, showing more greenish than reddish tones. This can be explained by the surface browning during high-heat methods, which enhances redness (a^*), especially in samples with higher meat content (Fernández-Ginés et al., 2003). Interestingly, the b^* values increased in both cooking methods, showing more bluish than yellowish tones as the meat content decreased and the mushroom content increased. This indicates that both the cooking method and formulation affect b^* values, but grill-induced crust development can mask the underlying colour changes caused by ingredient ratios (García-Segovia et al., 2007).

While measuring the rheological parameters, a clear decreasing trend was seen in both maximum force and adhesive work area, indicating that the strength and general elasticity of the burger patty decreased with the addition of mushroom (Bakhsh et al., 2021; Arun et al., 2021). Moreover, a statistical analysis (repeated measures ANOVA) showed a clear correlation between the meat–mushroom content and the measured results, with only minor measurement errors (Bakhsh et al., 2021).

Visual shrinkage measurements also showed a clear and visible pattern, similar to the yield results, and essentially indicated the same trend (Dikeman et al., 2005; Mazumder et al., 2023; Zhuang & Savage, 2011).

Lastly, the sensory analysis for customer acceptance revealed that, in line with our aim to preserve the meat taste while increasing healthiness by reducing meat and increasing mushroom content, general customer acceptance was achieved. In the case of grilling, acceptance was met only up to the 50/50 mixture, and in the case of oven baking, up to the 60/40 mixture—indicating a general trend and consumer preference for grilled products (Sogari et al., 2023; Yuan et al., 2021; Michel et al., 2021).

6. Conclusions and Suggestions

Based on the observed parameters of oyster mushroom, such as physical, techno-functional, and sensory, there is a particular possibility to introduce it as a partial meat replacement in ground beef burger patties. The initial aim of the study was to obtain the results of the experiment that could reveal whether partial substitution would be suitable for mass production, as well as acceptable to customers who are not willing to change their dietary habits significantly. The results of the analysis of the data obtained showed that not all of the combinations can be deemed suitable.

Oven-baked patties containing lower meat amounts demonstrated superior yield performance, which makes this processing method suitable for industrial production. The yield measurements for grilled samples decreased after meat reduction, which could restrict industrial production.

The colour evaluation of L^* , a^* and b^* values confirmed that oyster mushroom proportion did not significantly change the colour but resulted in minor shifts. The lightness of the product slightly increased, yet redness and yellowness decreased when the mushroom content increased.

The addition of high levels of oyster mushroom beyond 50% resulted in structural instability according to rheological measurements. These products displayed a loose structure, which caused them to break apart easily, thus rendering them useless for manufacturing operations. The texture integrity decreased as measured by both maximum piercing force and adhesive work area when mushroom content increased.

Visual shrinkage analysis showed that grilling led to greater shrinkage than oven baking. The results from yield data support oven baking as the better method to produce meat-reduced patties with acceptable physical attributes.

Consumer acceptance ratings remained stable when oyster mushroom content reached 40%, while beef content reached 60% in samples. The 20% mushroom to 80% meat ratio produced the best sensory scores since it matches consumer preferences. Sensory scores decreased when the oyster mushroom ratio exceeded 40%, indicating that excessive meat reduction led to decreased acceptance.

The replacement of meat with oyster mushroom in burger patties shows promise for the food production sector. According to our research, the maximum acceptable oyster mushroom

ratio for production should remain at 40% to preserve product integrity and consumer acceptance, as well as manufacturing capabilities.

Multiple additional steps should be taken to validate these research findings. An expanded sensory analysis with a larger participant group from diverse demographics should be conducted to better understand consumer acceptance. The results would become more generalisable to consumer acceptance through this method. Evaluating market implementation feasibility requires comparisons to existing industrial standards and production regulations, as well as labelling requirements. A detailed nutritional analysis should be performed to determine how substituting oyster mushrooms for meat affects the nutritional content of the finished product. The nutritional analysis must determine the protein content, as well as the presence of saturated and unsaturated fats, along with dietary fibre, vitamins, minerals, and carbohydrates. The nutritional data will validate health claims while quantifying the dietary advantages of meat-reduced patties.

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MATE Organizational and Operational Regulations

III. Requirements for Students

III.1. Study and Examination Regulations

Appendix 6.13: The MATE Uniform Thesis /thesis / final thesis / portfolio guidelines

Annex 4.2: Declaration of public access and authenticity of the thesis/thesis/dissertation/portfolio

DECLARATION

the public access and authenticity of the thesis

Student's name: Mazurova Arina
Student's Neptun code: LL6XLK
Title of thesis: BSc Thesis
Year of publication: 2025
Name of the consultant's institute: Hungarian University of Agriculture and Life Sciences
Name of consultant's department: Department of Livestock Product and Food Preservation Technology

I declare that the final thesis submitted by me is an individual, original work of my own intellectual creation. I have clearly indicated the parts of my thesis or dissertation which I have taken from other authors' work and have included them in the bibliography. Furthermore, I declare that the artificial intelligence tools (e.g. text generation, linguistic correction, translation, data analysis) used during the preparation of the thesis did not substitute my own research and creative work; their use was indicated either in the list of sources or in the methodology section, and I acted in accordance with professional and ethical expectations.

If the above statement is untrue, I understand that I will be disqualified from the final examination by the final examination board and that I will have to take the final examination after writing a new thesis.

I do not allow editing of the submitted thesis, but I allow the viewing and printing, which is a PDF document.

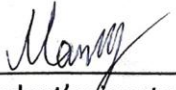
I acknowledge that the use and exploitation of my thesis as an intellectual work is governed by the intellectual property management regulations of the Hungarian University of Agricultural and Life Sciences.

I acknowledge that the electronic version of my thesis will be uploaded to the library repository of the Hungarian University of Agricultural and Life Sciences. I acknowledge that the defended and

- not confidential thesis after the defence
- confidential thesis 5 years after the submission

will be available publicly and can be searched in the repository system of the University.

Date: 2025 year 10 month 30 day



Student's signature

DECLARATION

Mazurova Arina (name) (student Neptun code: LL6XLK)
as a consultant, I declare that I have reviewed the final thesis and that I have informed the student of the requirements, legal and ethical rules for the correct handling of literary sources.

I recommend / **do not recommend**¹ the final thesis / dissertation / portfolio to be defended in the final examination.

The thesis contains a state or official secret: yes no^{*2}

Date: Budapest, 2025 October 30.


insider consultant

¹ The appropriate one should be underlined.

² The appropriate one should be underlined.

Declaration of Students and Doctoral Candidates on the Use of Artificial Intelligence (AI)”

1. General information:

Name of the student:	Mazurova Arina
Neptun ID:	LL6XLK
Level of program (mark with X):	<input checked="" type="checkbox"/> BSc/BA <input type="checkbox"/> MSc/MA <input type="checkbox"/> Doctoral School (PhD) <input type="checkbox"/> Other:
Name and code of the subject*:	Thesis Work
Title of the work:	BSc Thesis

* Not required to be completed in the case of a doctoral dissertation.

2. Declaration on the Use of AI

I, the undersigned, fully aware of my ethical responsibility, make the following declaration:

(Please choose one of the options below!)

A) I have not used any artificial intelligence system or service.

(If you selected this option, completing the subsequent tables is not required.)

B) I have used an artificial intelligence system or service.

(Please fill in the relevant tables!)

3. Details of Artificial Intelligence Usage

TABLE I: Assistant or Minor Usage (e.g., translation, language proofreading, brainstorming, etc.)

(For these uses, attaching the specific prompts and responses is not required.)

Purpose of Use	Name and Version of the AI Tool Used	Affected Section (if not applicable to the entire text)
Text polishing and correction of grammar and style	ChatGPT (GPT-5) by OpenAI	Introduction; Literature Review – Drivers of Meat Consumption; Results and Discussion – Sensory Analysis Measurement of Meat-Reduced Mushroom-Based Burger Patty Samples

TABLE II: Significant Content Contribution (e.g., generating an entire figure or a longer text section)

(In these cases, documenting the key prompts used and the raw responses provided by the AI, and attaching them as an appendix to the work, is required.)

Purpose of Use	Name, Version, and Access Information of the AI Tool Used	Exact Number of the Affected Chapter / Figure / Table	Entry Number of the Appendix Containing the Prompt Log
_____	_____	_____	_____

3/A. Additional Rules Prescribed by the Lecturer (if any)

If the instructor or supervisor of the course has established specific rules or expectations regarding the use of AI tools, please summarize them in the field below:

For example: prohibition of AI use for certain types of tasks; only specific tools are permitted; different citation requirements; documentation format, etc.

Rules Prescribed by the Lecturer or Supervisor

.....

4. Declaration Applicable to All Students:

I declare that I have critically reviewed, edited, and incorporated any content potentially generated by AI in all cases. I take full responsibility for every element of the submitted work, including its originality and scientific validity. I acknowledge that the Hungarian University of Agriculture and Life Sciences may check the submitted work with an artificial intelligence detector and may initiate proceedings if my declaration is found to be false or incomplete.

Place and Date: Budapest, 2025. 10 month 30 day

Mauilly
 Signature of the Student

Keri Gy
 Signature of the Advisor/Supervisor