Continental J. Applied Sciences
Oluwafemi and Oladimeji (2025) 20 (3): 118 – 133 Doi: 10.5281/zenodo.21350787

Research Article

Influence of Different Salts and Ionic Strength on the Protein Solubility of Selected Edible Mushroom Species

Temitope Nike Oluwafemi* and Esther Funmilayo Oladimeji
Department of Food Science and Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria. *Corresponding author: tnoluwafemi.fst@gmail.com

Abstract

One of the most critical functional properties that define the nutritional value and industrial utility of mushroom proteins is their solubility. Five food-grade sodium salts, including sodium chloride (NaCl)*, sodium sulfate* ($NaSO_4$)*, sodium sulfite* ($NaSO_3$)*, sodium acetate* (CH_3COONa)*, and sodium nitrite* ($NaNO_2$)*, were used to assess the impact on protein solubility of seven different mushroom samples (Lentinus subnudus Berk* (M_1)*, Chlorophyllum molybditis* (M_2)*, Volvariella esculenta* (M_3)*, Coprinus tramentarius* ($M)_4$*, Pleurotus ostreatus Jacq* (M_5)*, Termitomyces microcarpus* (M_6)*, and Pleurotus pulmonarius* (M_7)*) at different concentrations ranging from 2-12% w/v. Solubility was evaluated in triplicate, and statistically significant differences between treatments were calculated using ANOVA at the $p<0.05$ level. The results show clear differences in protein solubility for the selected mushroom samples and among salts. Protein solubility in all mushroom species* M2 *exhibited the highest value in nearly all salt treatments, with values of about 54% for the protein from* NaCl *and* $NaNO_2$*. The lowest values were obtained in* M5, M6, and M7*, with little variation depending on the salt used. Mushroom samples responded differently to protein solubility against increasing salt concentration, indicating different interactions among the proteins and dissolved ions of the specific mushroom species. Among the evaluated salts,* NaCl *and* $NaNO_2$ *gave generally higher protein solubility values than* $NaSO_4$ *and* CH_3COONa*, whereas* $NaSO_4$ *yielded intermediate effects depending on the mushroom samples. These findings are important in the process development for extraction and production of food ingredients with appropriate functional characteristics of mushroom protein.*

Keywords: Mushroom protein; Protein solubility; Sodium chloride; Ionic strength; Functional properties; Edible mushrooms

Received: 12 June 2025 **Accepted: 24 October 2025**

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Citation: Oluwafemi, T.N. and Oladimeji, E.F. (2025). Influence of Different Salts and Ionic Strength on the Protein Solubility of Selected Edible Mushroom Species. Continental J. Applied Sciences, 20(3), 118-133. Doi: 10.5281/zenodo.21350787

Introduction

Edible mushrooms are traditionally valued not just as culinary delights but also as part of the human diet. They offer significant amounts of protein, lipids, amino acids, glycogen, vitamins, and mineral salts (Okwulehie & Odunze, 2004). Studies have shown that the mineral content of mushrooms surpasses that of meat, fish, and nearly doubles that of most common vegetables (Adeyeye et al., 2008). Additionally, these fungi have a history of use for medicinal purposes (Selvi et al., 2007). Nigeria, with its diverse ethnic groups, including the Hausas of the North, Yorubas of the South West, Urhobo of the Mid - West, and Ibos of the East, has long identified various mushrooms and utilized them for economic and medicinal purposes (Ukoima et al., 2009a). Among the Yorubas, mushrooms have been integral to daily life for centuries, with each species bearing a descriptive Yoruba name and often associated with folklore and beliefs about their origins (Okhuoya et al., 2010). These traditions can influence the perception of edibility or medicinal value among native Yoruba doctors (Kuforiji & Fasidi, 2008). Typically, edible mushrooms are classified into five categories based on the origin of their names: those related to taste, morphology, growth habit, texture, and habitat (Osemwegie et al., 2006).

Based on taste, *Volvariella volvacea* and *Volvariella exculenta* are known as Ogiriagbe, and *Termitomyces clypeatus* as Takete. Morphologically, *Termitomyces mammiformis* is called Rooro, and *Termitomyces robustus* as Ewe. *Schizophyllum commue* Fr is identified as Ese-adie, and *Agrocyber broadway* as Gunnugu. Those named for their growth habits are *Termitomyces globules* and *Pleurotus tuber-reguim*) as Olu, while based on texture, *Pleurotus squarrosulus* is Erirokiro and *Psathyrella atroumbonata* as Wowo. The fungus *Francolimus bicalcaratus* is called Isoaparo due to its tendency to grow where the droppings of this bird are present. Natives also named many fungi after the specific type of dead wood they grew upon (Okhuoya et al., 2010). Besides edible mushrooms, the natives are also aware of toxic or inedible varieties, such as *Coprinus africans* (Ajeimutin), *Phallus aurantiacus*, *Phallus industiatus*, *Phallus rubicundus*, and *Mutinus bambustnus* (collectively Akufodewa), *Celtis zenkeri* (Asa-ita), and *Coprinus enphemerus* (Olu-gbongaga).

Although the nutritional and medicinal benefits of mushrooms have been established for some time (Manzi et al., 2001; Kettawan et al., 2011), their consumption was previously primarily noted in rural areas of Nigeria. However, there has been a recent increase in their importance in the diets of both rural and urban dwellers, with significant trade observed along major highways and in urban centres (Choudhury et al., 2025). This heightened demand is likely driven

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

by the rising costs of conventional protein sources such as beef, pork, chicken, fish, and eggs (Sangeeta et al., 2024).

The edible mushrooms attracted increasingly attentions among scientists and the food industry in terms of being an economical source of high-quality protein, fiber, vitamins, minerals, and several bioactives while low in fat (Ionescu et al., 2025). Due to their favorable amino acid profile, high digestibility, and various health-promoting compounds, they are used as important food ingredients in functional foods and in plant-based diets (Das et al., 2021). Besides nutritional merits, edible mushrooms also offer a series of functional properties that determine their application in the food processing industry (Aguiar et al., 2026). Among them, protein solubility is one of the most significant ones as it is directly associated with water-holding capacity, emulsion and foaming ability, gelling ability, as well as the efficiency of extraction of proteins.

It can be affected by various factors such as pH, temperature, ionic strength, type and concentration of dissolved salts. Salts can be added in food products in a wide range of concentrations to either increase or decrease the protein solubility of food products (salting-in and salting-out effects, respectively) (Cao et al., 2026). Each salt will interact with protein molecules with a different mechanism due to the unique characteristics of ions such as hydration ability and electrostatic potential and the changes induced on protein configuration (Dumetz et al., 2007; Karabulut et al., 2024). Therefore, it is worthwhile to examine the effects of different kinds of sodium salts on the solubility of mushroom protein.

Many studies (Chang, 1996; Dimopoulou et al., 2022; Hait et al., 2025) have been carried out on the nutritional composition and some functional properties of edible mushrooms, but systematic comparative analysis of the effects of different types of sodium salts on protein solubility in various mushroom species under the same conditions are very limited.

This kind of research may offer useful information to food processors who want to use mushroom protein as food ingredients and develop food processing technologies for optimal protein extraction from mushrooms. Hence, in this study, the impacts of five food-grade sodium salts (NaCl, $NaSO_2$, $NaSO_4$, CH_3COONa and $NaNO_3$) on the protein solubility of seven edible mushrooms (M1-M7) at various concentrations (2–12%) were investigated to shed light on the influence of ionic environment on protein functional characteristics.

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Materials and Methods

Source of Materials and Sample Pre-treatment

The mushrooms: *Lentinus subnudus* Berk (M_1), *Chlorophyllum molybditis* (M_2), *Volvariella esculenta* (M_3), *Coprinus tramentarius* (M_4, *Pleurotus ostreatus* Jacq (M_5), *Termitomyces microcarpus* (M_6), and *Pleurotus pulmonarius* (M_7) were collected from the Federal College of Agriculture campus, Akure, Ondo State, Southwest part of Nigeria. The bad or rotten samples were sorted out. The samples were oven-dried at 65^{o}C for 72 hours and were then ground into powder form using a porcelain pestle and mortar. The milled samples were then sieved with a 2 mm mesh-sized sieve and stored in waterproof polyethylene bags at room temperature for further analysis.

Determination of Protein Solubility in Salt Solutions

0.2g of each flour sample and 10ml of a particular salt concentration were thoroughly mixed with a magnetic stirrer (1000 rpm) at room temperature (30^{o}C). Insoluble materials were removed by centrifuging at 3500rpm for 30min. The supernatant was dissolved by the Biuret method. The salts used were sodium nitrite, sodium nitrate, sodium chloride, sodium acetate, sodium sulphate with their concentrations ranging between 2 and 12%). The nitrogen was converted to crude protein by multiplying by 6.25.

3.6 Statistical Analysis

Data obtained were generated in triplicates and analyzed using Mean, Standard deviation and one-way analysis of variance with Duncan Multiple Range test at 95% confidence or $p< 0.05$

3.7 The Null Hypothesis

1 There is no significant difference in the proximate composition of mushroom samples.
2. There is no significant difference in the mineral composition of mushroom samples.
3. There is no significant variation in the phytate levels of the mushroom samples.
4. There is no significant variation in the functional properties of the mushroom samples as different salt concentrations are used.

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Table 1: The Result of Effect of NaCl on Protein Solution (%) of Mushroom Sample

Salt Conc (%)	M_1	M_2	M_3	M_4	M_5	M_6	M_7
2	33.15 ± 2.02^{c}	46.15 ± 2.02^{b}	56.31 ± 2.70^{e}	18.24 ± 2.04^{a}	7.31 ± 2.07^{a}	21.18 ± 2.03^{d}	14.28 ± 2.06^{b}
4	28.17 ± 2.02^{b}	45.03 ± 2.00^{ab}	17.28 ± 2.06^{d}	16.25 ± 2.05^{a}	7.31 ± 2.07^{a}	15.03 ± 2.00^{a}	12.26 ±2.05^{ab}
6	24.01 ± 2.08^{a}	43.10 ± 2.00^{ab}	20.32 ± 2.08^{a}	17.28 ± 2.06^{a}	8.21 ± 2.04^{ab}	8.13 ± 2.01^{a}	10.27 ±2.56^{a}
8	21.02 ± 2.02^{a}	42.29 ± 2.06^{a}	26.02 ± 2.00^{b}	22.07 ± 2.00^{b}	12.06 ± 2.00^{c}	11.16 ± 2.02^{a}	9.05 ±2.00^{a}
10	21.11 ± 2.01^{a}	50.00 ± 2.00^{c}	32.28 ± 2.60^{c}	23.02 ± 2.00^{b}	11.22 ± 2.04^{bc}	14.04 ± 2.00^{bc}	9.20 ±2.03^{a}
12	22.02 ± 2.00^{a}	54.01 ± 2.00^{d}	31.24 ± 2.04^{c}	23.24 ± 2.04^{b}	12.23 ± 2.04^{c}	13.26 ± 2.05^{bc}	10.09 ±2.01^{a}

All values were expressed as the average of triplicate determinations ± the standard deviations, and values bearing the same superscripts in the same row are significantly not different (p<0.05).

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Table 2: The Result of Effect of Na_2SO_4 on Protein Solution (%) of Mushroom Samples

Salt Conc (%)	M_1	M_2	M_3	M_4	M_5	M_6	M_7
2	29.13 ± 2.20^{b}	41.102± 2.00^{ab}	18.04 ± 2.00^{b}	27.21 ± 2.03^{c}	12.16 ± 2.01^{bc}	7.06 ± 2.00^{a}	13.05 ± 2.00^{a}
4	21.27 ± 2.05^{b}	43.25 ± 2.04^{c}	16.24 ± 2.04^{b}	28.10 ± 2.01^{c}	13.24 ± 2.04^{c}	6.27 ± 2.06^{a}	10.06 ±2.00^{a}
6	24.01 ± 2.00^{a}	37.32 ± 2.07^{ab}	19.09 ± 2.01^{b}	17.21 ± 2.03^{a}	9.05 ± 2.00^{ab}	7.30 ± 2.07^{a}	10.20 ±2.05^{a}
8	23.02 ± 2.00^{a}	39.32 ± 2.01^{a}	10.13 ± 2.01^{a}	23.24 ± 2.04^{b}	11.22 ± 2.03^{abc}	8.33 ± 2.08^{a}	10.25 ±2.00^{a}
10	22.27 ± 2.05^{a}	36.05 ± 2.00^{a}	36.05 ± 2.00^{c}	20.15 ± 2.02^{ab}	9.05 ± 2.00^{ab}	7.22 ± 2.04^{a}	10.09 ±2.01^{a}
12	22.19 ± 2.05^{a}	36.20 ± 2.03^{a}	36.20 ± 2.03^{c}	20.01 ± 2.00^{ab}	8.21 ± 2.03^{a}	9.03 ± 2.00^{a}	10.17 ±2.02^{a}

All values were expressed as the average of triplicate determinations ± the standard deviations, and values bearing the same superscripts in the same row are significantly not different ($p<0.05$).

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Table 3: The Result of Effect of $NaSO_3$ on Protein Solution (%) of Mushroom Samples.

Salt Conc (%)	M_1	M_2	M_3	M_4	M_5	M_6	M_7
2	28.09 ± 2.01^{b}	45.08± 3.05^{c}	33.33 ± 2.08^{c}	19.12 ± 2.01^{c}	9.21 ± 2.03^{a}	9.15 ± 2.01^{a}	13.12 ± 2.01^{b}
4	29.25 ± 2.05^{b}	43.25 ± 2.05^{bc}	34.09 ± 2.01^{c}	20.15 ± 2.02^{ab}	15.18 ± 2.02^{b}	22.01 ± 2.00^{c}	10.09 ±2.01^{ab}
6	22.02 ± 2.00^{a}	39.24 ± 2.04^{ab}	28.11 ± 2.01^{b}	21.04 ± 2.00^{ab}	8.18 ± 2.02^{a}	12.2 ± 2.03^{ab}	10.06 ±2.00^{ab}
8	22.02 ± 2.00^{a}	45.18 ± 2.05^{c}	17.16 ± 2.01^{a}	23.31 ± 2.07^{bc}	17.22 ± 2.03^{b}	14.12 ± 2.01^{b}	10.17 ±2.02^{ab}
10	20.25 ± 2.00^{a}	36.05 ± 2.00^{a}	27.25 ± 2.00^{c}	26.11 ± 2.05^{c}	22.11 ± 2.01^{c}	13.26 ± 2.05^{b}	9.08 ±2.01^{a}
12	30.16 ± 2.01^{b}	41.17 ± 2.02^{bc}	26.21 ± 2.03^{b}	26.19 ± 2.03^{c}	17.09 ± 2.01^{b}	15.27 ± 2.05^{b}	10.32 ±2.08^{ab}

All values were expressed as the average of triplicate determinations ± the standard deviations, and values bearing the same superscripts in the same row are significantly not different ($p<0.05$).

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Table 4: The Results of the Effect of CH_3COONa on Protein Solubility (%) of Mushroom Samples

Salt Conc (%)	M_1	M_2	M_3	M_4	M_5	M_6	M_7
2	29.13 ± 2.20^{b}	41.02± 2.00^{bc}	18.04 ± 2.00^{b}	27.21 ± 2.03^{c}	12.16 ± 2.02^{bc}	7.06 ± 2.00^{a}	13.05 ± 2.00^{a}
4	21.27 ± 2.05^{a}	45.00 ± 2.00^{c}	16.24 ± 2.04^{b}	28.10 ± 2.01^{c}	13.24 ± 2.04^{c}	6.00 ± 2.00^{a}	10.06 ±2.00^{a}
6	24.01 ± 2.00^{a}	37.32 ± 2.07^{ab}	19.09 ± 2.01^{b}	17.21 ± 2.03^{a}	9.05 ± 2.00^{ab}	7.30 ± 2.07^{a}	10.21 ±2.03^{a}
8	23.01 ± 2.00^{a}	39.10 ± 2.01^{ab}	10.13 ± 2.01^{a}	23.24 ± 2.04^{b}	11.22 ± 2.04^{abc}	8.33 ± 2.07^{a}	10.25 ±2.04^{a}
10	22.27 ± 2.00^{a}	36.05 ± 2.00^{a}	36.05 ± 2.10^{c}	20.15 ± 2.02^{ab}	9.05 ± 2.00^{ab}	7.22 ± 2.04^{a}	10.09 ±2.01^{a}
12	22.19 ± 2.03^{a}	36.20 ± 2.03^{a}	36.20 ± 2.03^{c}	20.01 ± 2.00^{ab}	8.21 ± 2.03^{a}	9.03 ± 2.00^{a}	10.17 ±2.03^{a}

All values were expressed as the average of triplicate determinations ± the standard deviations, and values bearing the same superscripts in the same row are significantly not different ($p<0.05$).

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Table 5: The Results of the Effect of $NaNO_2$ on Protein Solubility (%) of Mushroom Samples

Salt Conc (%)	M_1	M_2	M_3	M_4	M_5	M_6	M_7
2	31.16 ± 2.02^{b}	53.19± 2.03^{b}	15.30 ± 2.07^{a}	25.08 ± 2.01^{a}	16.08 ± 2.01^{bc}	6.20 ± 2.00^{a}	14.09 ± 2.01^{a}
4	26.09 ± 2.01^{a}	50.01 ± 2.00^{b}	22.31 ± 2.07^{b}	38.03 ± 2.01^{b}	17.17 ± 2.02^{bc}	9.19 ± 2.02^{ab}	12.29 ±2.06^{a}
6	28.16 ± 2.02^{ab}	45.03 ± 2.00^{a}	32.28± 2.06^{c}	16.62 ± 1.47^{c}	9.05 ± 2.00^{a}	14.12 ± 2.07^{a}	13.24 ±2.04^{a}
8	25.09 ± 2.01^{a}	46.29 ± 2.06^{a}	39.68 ± 2.07^{d}	41.26 ± 2.05^{c}	18.26 ± 2.05^{bc}	19.17 ± 2.02^{c}	13.38 ±2.51^{a}
10	30.07 ± 2.00^{b}	44.07 ± 2.00^{a}	36.27 ± 2.06^{cd}	48.18 ± 2.02^{d}	19.10 ± 2.1^{c}	16.05 ± 2.00^{de}	14.21 ±2.03^{a}
12	30.07 ± 2.11^{b}	51.11 ± 2.01^{b}	31.33 ± 2.08^{c}	54.28 ± 2.06^{e}	15.08 ± 2.00^{b}	11.32 ± 2.08^{bc}	15.14 ±2.02^{a}

All values were expressed as the average of triplicate determinations ± the standard deviations, and values bearing the same superscripts in the same row are significantly not different ($p<0.05$).

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Results and Discussion

Results in Table 1 showed the impact of NaCl on the PS of mushroom samples. The results for PS ranged from 9.05 ± 2.00% to 56.31 ± 2.70% and differed significantly ($p > 0.05$). The PS of M1, M3, M6, and M7 declined as the salt concentrations increased, whereas the PS of M2, M4, and M5 escalated with enhanced salt concentrations.

Results in Table 2 documented the effect of Na_2SO_4 on the PS of mushroom samples. The PS values oscillated between 6.27 ± 2.06% and 43.25 ± 2.04% and did not differ significantly ($p > 0.05$). The PS of M1, M2, M4, M5, and M7 dropped with greater salt concentrations, while that of M3 and M6 escalated with increased salt concentrations. Results in Table 3 illuminated the impact of $NaNO_2$ on the PS of mushroom samples. The PS values fluctuated between 6.27 ± 2.06 and 43.25 ± 2.04% and differed considerably ($p > 0.05$). The PS of M1, M2, M4, M5, and M7 fell with increasing salt concentrations, while M3 and M6 showed an increase in PS as salt concentrations increased.

Results in Table 4 presented the effect of CH_3COONa on the PS of mushroom samples. The PS varied from 6.00 ± 2.00 to 45.00 ± 2.00% and varied significantly ($p > 0.05$) among the samples. The PS of M1, M2, M4, M5, and M7 declined with increasing salt concentrations, whereas the PS of M3 and M6 escalated with increasing salt concentrations. Results in Table 5 revealed the effect of $NaNO_2$ on the PS of mushroom samples. The PS values oscillated between 6.20 ± 2.00 and 54.28 ± 2.06% and showed significant differences ($p > 0.05$). The PS of M1 and M2 showed a decrease with enhanced salt concentrations, whereas M3, M4, M5, M6, and M7 experienced an upswing in PS as salt concentrations increased.

Overall, Protein Solubility (PS) of most mushroom samples demonstrated a tendency to decrease as solubility enhanced at higher salt concentrations. These findings corroborated previous research on *Chenopodium quinoa* flour by Ogungbemile et al. (2009). The general decline in the PS of these samples can be attributed to the electrostatic shielding of the groups by the salts (Ogungbemile et al., 2009). The protein solubility values under different concentrations of sodium nitrite are detailed in Table 5. M2 displayed the highest solubility, and M6 exhibited the lowest. Samples M1, M3, and M4 recorded high values, while M5 and M7 showed low values, with the range of 5% to 21% for M5 - M7. These outcomes contrasted with Adeyeye & Aye (2005) findings for *Triticum durum* flour. The reduction in solubility across all mushroom samples might be a consequence of fungal denaturation. The PS of the samples under various sodium sulphate concentrations is presented in Table 2. M2 showed the highest solubility within the salt concentration range of 4%-12%, with the lowest being between 36.05 ± 2.00% and 43.25 ± 2.05%. The maximum peak of solubility for M2 occurred at

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

2%. All solubilities obtained were relatively low. Most of the samples had low PS at elevated salt concentrations, which aligns with the reports by Adeyeye & Aye (2005) and Ogungbemile et al. (2009). These low solubilities may arise from the denaturation of protein in all samples. The values obtained for the protein solubility of mushroom samples under the influence of sodium chloride are given in Table 1, with protein solubility ranging from 7.31 ± 2.07% (M5) to 56.31 ± 2.70% (M3). A decreasing trend in solubility was observed as salt concentration increased, possibly due to protein denaturation in the mushroom species. The solubility values of mushroom samples under different sodium nitrate concentrations are presented in Table 4, ranging from 6.27 ± 2.06% to 43.25 ± 2.05%. The solubility for M3, M4, and M5 remained fairly similar within the 4% to 8% salt concentrations. M2 exhibited a salting-out effect at salt concentrations of 6% and 10%. Therefore, sodium acetate does not appear to be an effective solubilizing salt for mushroom samples.

The findings indicated considerable variations in protein solubility among mushroom samples and salt treatments, underscoring the combined influence of intrinsic protein composition and ionic environment on protein behaviour. Significant differences ($p < 0.05$) among treatments suggest a strong dependence of protein-salt interactions on both salt type and concentration. Across all tested salts, sample M2 consistently yielded the highest protein solubility, often exceeding 40% and approaching 54% with NaCl and $NaNO_2$ treatments. This consistent pattern suggests a high affinity of M2 proteins for aqueous phases or unique structural features that facilitate dissolution under various ionic conditions (Bharmoria et al., 2024). In contrast, M5, M6, and M7 generally displayed low protein solubility irrespective of salt concentration, implying limited extractability or robust intermolecular protein interactions. NaCl demonstrated some of the highest protein solubility values amongst all treatments. Relatively moderate increases in NaCl concentration sustained elevated protein solubility in M2 while bolstering it in M3 and M4 at higher concentrations. This is reflective of the classical salting-in phenomenon wherein low to moderate ionic strength mitigates intermolecular electrostatic interactions, enhancing hydration and dispersal before excessive ion strength impedes further improvements (Agrawal et al., 2025).

$NaSO_4$ imparted relatively lower protein solubility to most mushroom samples. Sulfate ions are more strongly hydrated than chloride ions and generally promote salting-out effects at lower concentrations. This behaviour likely explains the comparatively modest enhancement observed for several mushroom samples when compared with NaCl. The response to $NaSO_4$ varied among different mushroom samples, revealing species-dependent protein-ion interactions. Although M2 maintained reasonably high solubility across all concentrations, others exhibited variability instead of steady increases. Such variation can be linked to differences in protein content, molecular weight distributions, and amino acid composition

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

among mushroom species. CH_3COONa yielded responses comparable to those of $NaSO_4$ for a few samples, though some mushroom proteins showed moderate increases at specific concentrations. This indicates that acetate ions can interact with mushroom proteins to influence hydration, though to a lesser extent than NaCl in promoting dissolution. $NaNO_2$ resulted in some of the most notable protein solubility enhancements, particularly for M3 and M4 at higher concentrations where values surpassed those under several other salt treatments. This amplified response suggests that nitrite ion interactions with mushroom proteins can enhance their dispersion under the prevailing experimental conditions.

Conclusion and Recommendations

Conclusion

This study demonstrated that protein solubility in mushrooms is significantly influenced by both the type of sodium salt and its concentration. Considerable variation was observed among the seven mushroom samples, confirming species-specific differences in protein functionality. NaCl and $NaNO_2$ generally produced the highest protein solubility, whereas Na_2SO_4 and CH_3COONa were comparatively less effective. Sample M2 consistently exhibited superior protein solubility across all treatments, while M5, M6 and M7 showed relatively low solubility irrespective of salt concentration. These findings highlight the importance of selecting appropriate extraction salts when developing mushroom protein ingredients for food applications. Future studies should investigate the effects of pH, temperature, protein composition and amino acid profiles to better understand the mechanisms governing salt-induced changes in mushroom protein functionality.

Recommendation

Based on the findings of this study, the following recommendations are proposed:

1. Sodium chloride (NaCl) should be considered as a preferred extraction medium for mushroom proteins because it consistently produced high protein solubility in several mushroom samples. Its effectiveness suggests potential application in the production of mushroom protein concentrates and functional food ingredients.
2. Protein extraction protocols should be optimized for individual mushroom species rather than adopting a universal approach. The considerable differences in protein solubility observed among the seven mushroom samples indicate that each species responds differently to changes in salt type and concentration.
3. Future studies should investigate additional processing variables, including pH, temperature, extraction time, and enzyme-assisted extraction, to identify the optimal conditions for maximizing protein yield and preserving functional properties.

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

4. Comprehensive characterization of mushroom proteins should be undertaken by determining amino acid composition, molecular weight distribution, protein digestibility, and structural changes induced by different salts. Such information would provide deeper insight into the mechanisms responsible for variations in protein solubility.
5. The functional properties of the extracted proteins, including emulsifying capacity, foaming ability, gelation, water-holding capacity, and oil absorption capacity, should be evaluated to determine their suitability for incorporation into different food formulations.
6. Further research should expand the range of mushroom species and extraction salts evaluated. Including both cultivated and wild edible mushrooms would provide broader knowledge that can support commercial processing and industrial utilization.
7. Industrial-scale validation of the extraction process is recommended to assess the economic feasibility, extraction efficiency, product quality, and environmental sustainability of using different salts in mushroom protein production.

References

Adeyeye E.I. & Aye P.A. (2005). Chemical composition and the effect of salts on the food properties of wheat flour. *Pakistan Journal of Nutrition*. 4: 187 –196.

Adeyeye E.I. & Adubiaro H.A. & Awodola, O.J. (2008). Comparability of chemical composition and functional properties of shell and flesh of *Penaecus notabilis. Pakistan Journal of Nutrition*. 7 (6): 741 – 747.

Agrawal, A., Gravelle, S., Holm, C., & Schlaich, A. (2025). Interfacial ion hydration and electrostatics govern salt precipitation and crystal morphology. *The Journal of chemical physics*, *163*(24), 244707. https://doi.org/10.1063/5.0299741

Aguiar, L. V. B. d., do Nascimento Soares, L. B., Lima-Silva, G., Pereira, D. B., Pessoa, V. A., dos Santos Vasconcelos, A., Pozzan, R., Lima Serra, J., Sales-Campos, C., Chevreuil, L. R., & Martínez-Burgos, W. J. (2026). Functional Foods from Edible Mushrooms and Mycelia: Processing Technologies, Health Benefits, Innovations, and Market Trends. *Fermentation*, *12*(4), 173. https://doi.org/10.3390/fermentation12040173

Bharmoria, P., Tietze, A. A., Mondal, D., Kang, T. S., Kumar, A., & Freire, M. G. (2024). Do Ionic Liquids Exhibit the Required Characteristics to Dissolve, Extract, Stabilize, and Purify

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Proteins? Past-Present-Future Assessment. *Chemical reviews*, *124*(6), 3037–3084. https://doi.org/10.1021/acs.chemrev.3c00551

Cao, R., Wang, W., Zhang, Z., Wang, C., Huang, Q., Yan, L., Zhang, J., & Cheng, J. (2026). Strategies for enhancing protein solubility: methods, applications, and prospects. *NPJ science of food*, *10*(1), 86. https://doi.org/10.1038/s41538-026-00743-5

Chang R. (1996). Functional properties of edible mushrooms. *Nutrition reviews*, *54*(11 Pt 2), S91–S93. https://doi.org/10.1111/j.1753-4887.1996.tb03825.x

Choudhury, S., Bi, A. Z., Medina-Lara, A., Morrish, N., & Veettil, P. C. (2025). The rural food environment and its association with diet, nutrition status, and health outcomes in low-income and middle-income countries (LMICs): a systematic review. *BMC public health*, *25*(1), 994. https://doi.org/10.1186/s12889-025-22098-4

Das, A. K., Nanda, P. K., Dandapat, P., Bandyopadhyay, S., Gullón, P., Sivaraman, G. K., McClements, D. J., Gullón, B., & Lorenzo, J. M. (2021). Edible Mushrooms as Functional Ingredients for Development of Healthier and More Sustainable Muscle Foods: A Flexitarian Approach. *Molecules (Basel, Switzerland)*, *26*(9), 2463. https://doi.org/10.3390/molecules26092463

Dimopoulou, M., Kolonas, A., Mourtakos, S., Androutsos, O., & Gortzi, O. (2022). Nutritional Composition and Biological Properties of Sixteen Edible Mushroom Species. *Applied Sciences*, *12*(16), 8074. https://doi.org/10.3390/app12168074

Dumetz, A. C., Snellinger-O'brien, A. M., Kaler, E. W., & Lenhoff, A. M. (2007). Patterns of protein protein interactions in salt solutions and implications for protein crystallization. *Protein science: a publication of the Protein Society*, *16*(9), 1867–1877. https://doi.org/10.1110/ps.072957907

Hait, M., Bhardwaj, A.K., Kashyap, N.K. (2025). Nutritional Composition and Value of Edible Mushroom. In: Izah, S.C., Ogwu, M.C., Akram, M. (eds) Bioactive Compounds in Edible Mushrooms. Reference Series in Phytochemistry. Springer, Cham. https://doi.org/10.1007/978-3-031-52642-8_14-1

Ionescu, M., Dincă, M. N., Ferdeş, M., Zăbavă, B. Ş., Paraschiv, G., & Moiceanu, G. (2025). Proteins from Edible Mushrooms: Nutritional Role and Contribution to Well-Being. *Foods (Basel, Switzerland)*, *14*(18), 3201. https://doi.org/10.3390/foods14183201

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Karabulut, G., Köroğlu, D. G., Feng, H., & Karabulut, Z. (2024). Sustainable fungi-based protein extraction from agro-waste mushroom stem using deep eutectic solvents. *Food Chemistry: X*, *24*, 101931. https://doi.org/10.1016/j.fochx.2024.101931

Kattawan A., Chanlekha K., Kongkachuichai R. & Chaaroensiri R. (2011). Effects of cooking on antioxidant activities and polyphenol content of edible mushrooms commonly consumed in Thailand. *Pakistan Journal of Nutrition*. 10 (11): 1094 – 1103.

Kuforiji O. & Fasidi I. (2008). Compositional studies on *Pleurotus tuber-regium* sclerotia. *Advances in Food Sciences*. 30 (1): 2-5.

Loria-Kohen, V., Lourenco-Nogueira, T., Espinosa-Salinas, I., Marin, F.R., Soler-Rivas, C., Molina, A.R. (2014). Nutritional and Functional Properties of Edible Mushrooms: A Food with Promising Health Claims. Journal of Pharmacy and Nutrition Sciences, 2014, 4, 187-198.

Manzi P., Aguzzi A. & Pizzoferrato L. (2001). Nutritive value of mushrooms widely consumed in Italy. *Food Chemistry*. 73: 321 – 325.

Ogungbemile, H.N., A.A. Oshodi & M.O. Oladimeji (2009). The proximate and effect of salt applications on some functional properties of Quinoa (*Chenopodium quinoa*) flour *Pakistan Journal of Nutrition*. 8 (1): 49 – 52.

Okhuoya J.A., Isikhuemhen O.S. & Evue G.A. (2010). *Pleurotus tuber-regium* (fr) sing. The sclerotia and sporophore yield during cultivation on saw dust of different woody plants. *International Journal of Mushroom Science*. 2: 41 – 46.

Okwulehie I.C. & Odunze E.T. (2004). Evaluation of the Myco-chemical and Mineral Composition of Some Tropical Edible Mushroom. *Journal of Sustainable Agriculture and Environment*. 6 (1): 63 – 70.

Osemwegie O.O., E.G. Eriyaremu & J. Abdulmahik (2006). A survey of macrofungi in Edo/Delta region of Nigeria, their morphology and uses. *Global Journal of Pure and Applied Science*. 12(2): 149 – 157.

Sangeeta, Sharma, D., Ramniwas, S., Mugabi, R., Uddin, J., & Nayik, G. A. (2024). Revolutionizing Mushroom processing: Innovative techniques and technologies. *Food chemistry: X*, *23*, 101774. https://doi.org/10.1016/j.fochx.2024.101774

ISSN: 3043–6087. Science and Education Development Inst., Nigeria

Selvi S., Uma Devi P., Suja S., Murugan S. & Chinnarswamy P. (2007). Comparison of non-enzymic antioxidant status of fresh and dried from of *Pleurotus florida* and *Calocybe indica, Pakistan Journal of Nutrition*. 6(5): 468 – 471.

Ukoima H.N., Ogbonnaya L.O., Arikpo G.E. & Ikpe F.N. (2009a). Cultural studies of mycelia of *Volvariella volvacea, Pleurotus tuber-regium* and *Pleurotus sajor caju* on different culture media. *Pakistan Journal of Nutrition*. 8(7): 1052 – 1054.

ISSN: 3043–6087. Science and Education Development Inst., Nigeria