Impact of pretreatments combined ~~to~~ (with) sun and oven drying, and canning methods on lovastatin content of *Pleurotus ostreatus*

sun-drying, oven-drying and canning

Abstract

Aims: Lovastatin is a cholesterol-lowering drug produced by several filamentous fungi as a secondary metabolite. (Its) ~~His~~ concentration in mushroom can be affected by many post-harvest processing. In this study, fruiting body of *Pleurotus ostreatus* grown on corn cobs was used to evaluate the effect of conservation techniques on lovastatin concentration.

Methodology: Pretreatment and ~~Different~~ (different) conservation method of fruiting body like sun drying, oven drying and canning was tested to evaluate their effect on lovastatin concentration.

Results: The concentration of lovastatin in fresh mushroom was 735.91±7.2µg/g of dried weight. Sun drying, oven drying at 60°C/70°C and canning after 100°C appertization did not significantly affect lovastatin concentration. On the contrary, oven drying at 80°C caused the reduction of this compound irrespective of the type of the pretreatment. The highest reduction in this case was about 45.4% (401.8 ± 24.8 µg/g of dry mushroom). Also, during canning, the use of appertization at temperatures higher than 100°C for 15 ~~min~~ (minute) caused a significant reduction of lovastatin concentration of about 52.2% and 48.9% respectively compared to the control. In this regards, it can be concluded that processes that use wet thermal treatments higher than~~t~~ 80°C and dry heat treatments higher than~~t~~ 100°C will contribute to the reduction of lovastatin, the cholesterol-lowering compoundin *Pleurotus ostreatus.*

Keys words: *Pleurotus ostreatus*, Conservation ~~techniques~~, Lovastatin ~~concentration~~, citric acid treatment ~~blanching~~, sun-drying, oven-drying.

1. Introduction

Fungi are the fleshy fruiting bodies and spores of a fungus produced using soil or agro waste [1]. In recent years, their worldwide production and consumption have increased significantly. The FAOSTAT database shows that the global production of mushrooms and truffles has increased significantly from 7.5 million tons in 2009 to 11.8 million tons in 2019 [2]. In accordance with what mushrooms represent in human nutrition and health, they can be classified into four classes: edible, medicinal, poisonous and other mushrooms, whose properties are not yet well defined [3]. Some comestible mushrooms also have medicinal properties and thus belong to the edible and medicinal groups simultaneously [4]. *Pleurotus ostreatus* belongs to the latter class. *P. ostreatus* has been preferred all over the world for many years due to its characteristic taste, agreeable aroma, culinary goodness, nutritional content, medicinal value, high yield, short life cycle and relatively easy growing method [5]. Mushrooms have a high nutritive value. They are rich in protein, dietary fiber, vitamins, minerals and phenolic compounds. Additionally, ~~mushrooms~~ (they) have a low fat content (composed mainly of unsaturated fatty acids) and a low energy density [3; 4; 6; 7]. They

Comment [u1]: This study is an interesting one and can contribute to the literature or existing knowledge. I appreciate the efforts of the authos to do this sort of experimental research with their own efforst without any financial assistance from any other body.
-Having said this, I want some clarifications and if authors agree some sort of revisions in the paper here and there.

??In the title, Which process is considered as pretreatment ?
And how do you show its impact as compared to after treatment impact ?
- The whole exercise in this experimental study is to show the difference in the level of **lovastatin content** in mushrooms before and after experimental treatmens are applied.
- So, impact analysis methods looks unsound.
- Rather than trying to tell the impact of pretreatment to mushrooms, it is better to examine the change in the content of **lovastatin content** after treatmen as compared to its natural setting. This is because, before treatments are applied, the mushrooms' **lovastatin content** is n its natural setting. The only thing that can be done is to measure the **lovastatin content** before treatments are applied, and then measuring again after treatments are applied.
- So, the word impact seems inappropriate.
- If the authors If the authors agree with this comment, the title seems to be reshafled.
-I recommends it to be reshafled as follows:
"The level of **lovastatin content in *Pleurotus ostreatus before and after treatements.*"**

Comment [u2]: Expand it it appears for the first time in the paper.

~~Mushrooms~~ are the unique non-animal source of vitamin D [4; 8; 7]. ~~Mushroom~~ They proteins are of high quality and have all essential amino acids required by humans [9]. Scientists from the University of Oxford [10] have asserted that the amino acid composition of mushroom proteins is comparable to that of animal proteins. The mycelia and fruiting bodies of *P. ostreatus* contain a wide range of bioactive compounds produced through the polyketide biosynthetic pathway. Statins, among these classes of fungal metabolites, have gained a great deal of attention due to their capacity to affect the *de novo* synthesis of endogenous cholesterol [11]. Lovastatin is the most widely prescribed drug for hypercholesterolemia in the world. It was the first statin that was approved by the US Food and Drug Administration in 1987 [12]. Lovastatin ($C_{24}H_{36}O_5$), a fungal secondary metabolite, is a competitive inhibitor of the enzyme hydroxyl methyl glutaryl coenzyme A (HMG-CoA) reductase, the enzyme that catalyzes the conversion of HMG-CoA to mevalonate during cholesterol biosynthesis. Inhibition of HMG-CoA reductase, during Cholesterol biosynthesis results in the accumulation of HMG-CoA which is metabolized into a simple compound and there are no lipophilic intermediates noted [13]. The predominant form of lovastatin in the fermentation broth is the open hydroxyl-acid form (mevinolinic acid). However, it is generally in the lactone form when given to patients as a drug. In vivo, the lactone form of the compound is being converted to the open hydroxyl-acid, which is the biologically active form of the statin [14]. The commercialization of fresh mushrooms, however, presents a main challenge: it is a highly perishable food product that has tendency to lose its quality directly after being harvested. Mushrooms have some characteristics that facilitate their rapid spoilage, namely high water content (85-95%) of fresh mushrooms [15], neutral pH, high respiration rate, high level of enzymatic activity, presence of microflora, and absence of protective cuticular layer on the skin [16; 17]. Previous studies have indicated a series of factors that may impact post-harvest mushroom quality attributes [17], grouping them into both internal factors associated with the mushroom itself (water activity, respiration rate, and microbial activity) and external factors related to storage (storage temperature, relative humidity, and mechanical damage). A recent review of post-harvest preservation techniques used to maintain the quality and extend the shelf life of mushrooms was conducted by Zhang et al [17]. These authors classified such conservation techniques into three groups: thermal, physical and chemical [17]. Some of these preservation methods, however, modify the chemical composition of mushrooms and, therefore, affect their nutritional value, bioactive properties, and organoleptic characteristics.

From the above discussion on the health benefits of some bioactive compounds that are present in mushrooms and taking into account all the factors that can influence their quality properties, the necessity of applying preservation methods to effectively reduce quality deterioration, extend shelf life, and conserve the nutritional value of fresh mushrooms is evident. The objective of this study was to evaluate the changes induced by different preservation treatments including sun-drying, oven-drying and canning on the lovastatin concentration of *Pleurotus ostreatus.*

2. Methodology

2.1. Mushroom strains

A pure culture of *Pleurotus ostreatus* was isolated from pileus tissue with sterile clamps by cutting longitudinally and transferring to Petri dishes containing potato dextrose agar (PDA) before incubating for 14 days at 25°C **[18].**

2.2. Spawn production

For spawn production, corn grains were used as substrate. Spawn medium was prepared according to [19] with slight modification. Each spawn medium was washed and soaked overnight, after this, water was drained, and they were boiled for 15 minutes with fresh water, and allowed to cool for 20 minutes. One hundred grams of each medium were transferred in tissue culture bottles, autoclaved at 121°C for 60 minutes, and allowed to cool. The bottles were inoculated with *P. ostreatus* mycelia and incubated for 14 days in the dark at 25°C.

2.3.Pleurotus ostreatus growing

Corn cobs ~~was~~ were used for cultivating *Pleurotus ostreatus.* All substrate supplements were mixed manually with water to reach approximately 90% moisture as suggested by [19]. The mixture (1500 g) was then packed in polypropylene sacks and the sacks were sterilized at 121 °C for 1 hour. After cooling the temperature to 25 °C, spawns were aseptically inoculated into the bags (100 g). The bags were then incubated in the dark in the mycelial growth room at a temperature of 25±1 °C, with a relative humidity of 60-75%. All assays were performed using six replicates arranged in the production room in a totally randomized way. After the mycelium had colonized the substrates of the bags, they were withdrawn in the dark for fruiting. The bags were kept at 25±1 °C, 70-80% humidity. Watering was done daily with a tap water sprayer until fruiting bodies were completely mature. Developed mushrooms were harvested after around 3-4 days from the initial fructification.

2.4. Pre-treatments, experimental design and treatments

2.4.1. Pre-treatments

The pretreatments administered to mushrooms before drying and awning were as follows: (a) blanching [B] in hot water at 93°C for 3 min, (b) dipping for 10 min in a solution containing 0,5 g/L citric acid [CA]. Untreated mushrooms were used as a control.

2.4.2. Experimental design

In this study, three distinct treatments were compared, sun-drying, oven-drying and canning. The experiment was performed in a completely randomized design (CRD) with three replications for each treatment. Three different drying methods were used, namely simple drying, drying after citric acid treatment and drying after blanching pretreatment. This was applied for sun and oven drying (figure 1 and 2). Before treatment, the fresh mushroom samples were firstly sliced into about 5 mm thick slices using a stainless steel knife. For each replicate of the drying treatments, 500 g of oyster mushrooms were used and for the canning treatment, 120 g were used. In the natural drying method, the mushroom samples were spread

Comment [u3]: Since the study methodology is basically experimental, I would prefer reorganizing of the subsections as :
2.1. Research design (include what you wrote in sub-section of 2.4.2
2.2. Pre-treatement process You can include here subsections, 2.1., 2.2., 2.3., 2.4.1.,
2.2. Experimental process
2.2.1. Treatement and its subsections as they are

Comment [u4]: What activity regarded as Pre-treatement ? Because, this sentence seems the beginning of treatments.
If the authors are interested in the pre-treatement process, they can describe the characteristics of mushrooms before treatments were applied ; they can also describe the process of preparation for treatement process.
But, what they mentioned here in a & b is the beginning of treatment because blanching in hot water and dipping in a solution are treatements that can change the original contents of the mushrooms. Or, they will not have similar character with the control group or untreated mushrooms.
Therefore. Revisit this section carefully.

Comment [u5]: What does « simple drying mean ?
You need to clarify in a simiple sentence the kind of drying you applied in this regard. If you want to mean sun drying without any additional substance, tell the reader that.

on perforated trays and sun-dried. The samples were mixed at regular intervals to ensure uniform drying.

2.4.3. Treatments

2.4.3.1. Drying Processes

Two drying processes were used in this study: sun drying (figure 1) and oven hot air drying (figure 2). For oven drying, mushrooms were dried with hot air at 60, 70 and 80°C with an air flow rate of 1.5 m/s up to 85% moisture. The material loaded on the tray was weighed constantly. The air was electrically heated prior to entering the dryer. Following drying, all samples were ground in an electric mill individually and sieved through an 80 mesh screen to obtain fine powders. The obtained powder was cooled, packed hygienically and stored in a hermetic container for later usage.

2.4.3.2. Canning process

After pretreatments, mushrooms were blanched and pasteurized at different temperatures including 100, 110 and 121°C for 15 min. After canning, all samples were analyzed for the presence of total aerobic mesophilic flora and total aerobic spore flora content after 1 month of conservation in comparison to the control that was not bleached. In addition, a visual analysis was done to observe the presence of cloudiness characteristic of the presence of microbial contamination. The canned mushrooms were subjected to a microbiological quality assessment directly after production and their stability was evaluated over a period of 3 months. For this purpose, the following flora were analyzed: total aerobic mesophilic flora and total aerobic spore flora. Following the enumeration, a visual evaluation of the stability marked by the development or not of the microorganisms was also carried out every week for the different conditions (figure 3).

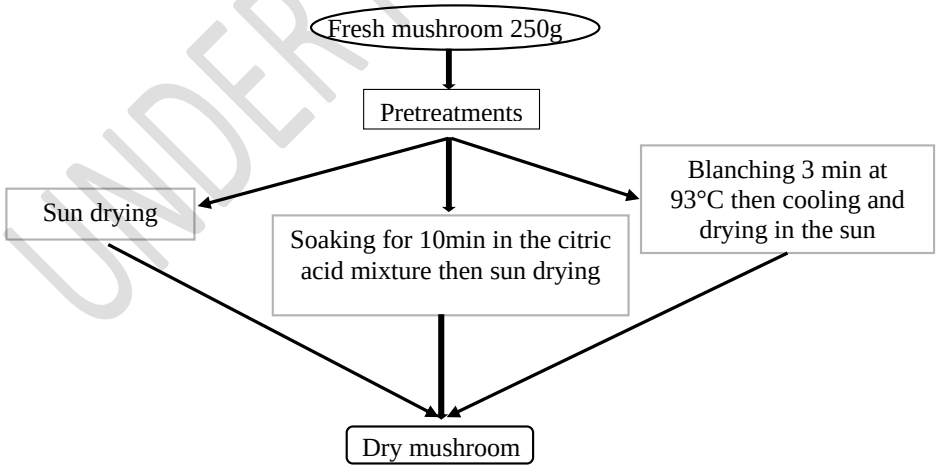

Figure 1: Protocol of sun drying processing

Comment [u6]: This framework used to show the protocol of treatment needs revision because there is any activity or process that shows pretreatement. WHat the authors mentioned in the middle three boxes are treatment process/activities

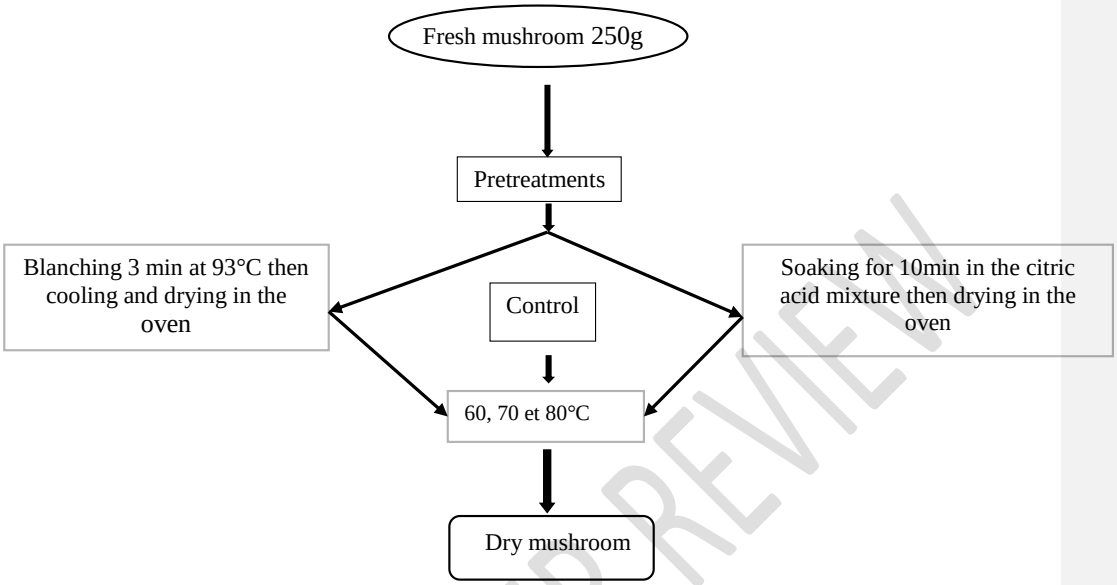

Figure 2: protocol of Oven drying processing

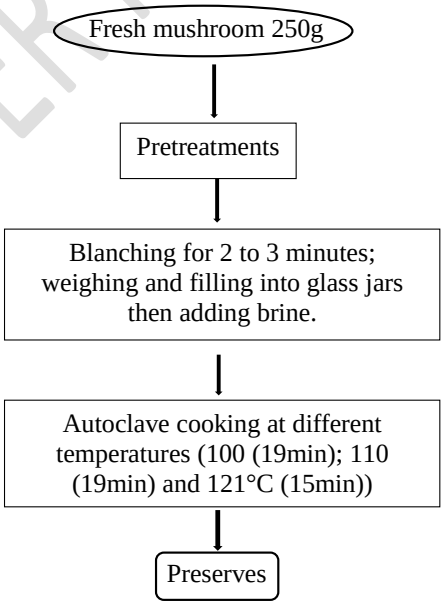

Figure 3: protocol of Canning processing

2.5. Determination of lovastatin

2.5.1. Preparation of lovastatin standard and standard curve

The beta hydroxyl acid form of lovastatin being the most produced by mushrooms, this was the form used for the lovastatin curve and was determined by UV/Vis spectrophotometer analysis at 238nm. Also, the beta hydroxyl acid is quite stable in solution **[20].** Tablets of pharmaceutical-grade lovastatin (Lovastatin STADA®, lactone form) containing 40 mg of lovastatin per tablet was used to prepare the standards for the assays. The hydroxy acid form of lovastatin was prepared from tabled by hydrolysis as described by Yang and Hwang **[21].** To obtain a stock solution of 20 mg/ml,lovastatin was dissolved in acetonitrile and other dilutions in acetonitrile were performed to have different concentrations which optical density (OD) was read by a UV/Vis spectrophotometer (Genesis 10S) at 238nm. A calibration curve was hence obtained. The absorbance of different solutions with concentrations ranging from 7 to 125 µg/ml was determined and a standard plot was realized to obtain a linear curve. The equation obtained was used to determine the lovastatin concentration present in mushroom extracts.

2.5.2. Extraction of lovastatin from *P. ostreatus*

This was carried out according to **[22].** The test excluded the conversion step to the lactone form.Three grams of the mushroom powder were taken in a test tube and mixed with 50ml of ethyl acetate. Extraction of lovastatin was carried out by sonication for 45min, before filtration using Whatman No. 1 filter paper. The residual material was washed three times using ethyl acetate. The liquid phase was dried under a vacuum in a rotary evaporator at 45°C. The dried residue was dissolved in 2ml acetonitrile and used to determine the lovastatin content by UV/Vis spectrometry**.** All the concentration was determined based on dry product basis.

~~2.6.Data Analysis~~

The data set was statistically analyzed for the mean difference using an LSD post hoc test with significant differences were considered for $P<0.05$. Statistical analysis of the effect of different factors on lovastatin concentration was also performed using hypothesis decomposition by multivariate ANOVA analysis.

3. Results and Discussion

The cultivation of mushrooms is a rather complex process that allows the production of a highly perishable product that need to be preserved. In fact, many mushrooms have become

Comment [u7]: 2.5. Method of data analysis
2.5.1. Preparation of lovastatin standard and standard curve
-maintain the remaining subsections as they are.

Comment [u8]: Include this paragraph as a spring board (introduction) to data analysis method

attractive because much research has focused on their health benefits, attributed to their bioactive compounds as reviewed in detail by different authors **[23, 24, 25, 26, 27, 28, 29]**. The chemical and nutritional attributes of mushrooms are interrelated not only to species but also to processing **[30, 31, 32]** and cooking **[33, 34, 35]**. Our experiment was focused on the stability of lovastatin after different transformations processes.

3.1. *Variation of lovastatin concentration during solar drying according to treatments*

Drying is a frequent and the most used preservation method used on mushrooms **[36, 37]**. In our study, different drying techniques were used compared to fresh mushroom. Lowering the pH is generally used to convert most of the acidic form to the quantifiable lovastatin lactone form **[38, 39, 40, 41].** However, most reports recognize that incomplete hydrolysis often occurs under these conditions, and that equilibrium between the lactone and acid forms is always present. For this reason, some studies have focused on the conversion of the lactone form of lovastatin to the acid form under alkaline conditions. In such cases, most lovastatin is present in the more stable hydroxy acid form **[42, 43, 44, 45, 46, 47, 48, 49].** In our work, lovastatin was extracted in neutral medium and under these conditions lovastatin is present in both forms; the acidic form being predominant, which is in line with **[22;50].** Our results show that the lovastatin concentration present in the fresh mushroom was 735.9 ± 7.2 µg/g on dry weight basis and that solar drying without any pretreatment does not affect this concentration. In their work **[50]** also demonstrated that sun drying did not affect the concentration of statin. However, blanching and citric acid treatment before drying significantly affected this concentration. In fact, the acid pre-treatment with citric acid followed by sun drying is considered as combined treatments inducing a higher detection of lovastatin; 1471.7 ± 11.3 µg/g of dry mushroom compared to 735.9 ± 7.2 µg/g fresh mushroom (control). It is obvious that there is no creation of lovastatin after a treatment with respect to the fresh product. As mentioned previously, in fungi, lovastatin can be present in both its lactone and hydroxy acid form. This bioconversion is bidirectional and significantly affected by the prevailing pH conditions **[51]**. At low pH, most of the acidic form is converted to the quantifiable lovastatin in the lactone form, although equilibrium is still present **[52]**. Therefore, culture conditions, special pretreatments, or pH adjustments during analysis may affect the ratio of the two forms of lovastatin. In our case, the treatment in acidic medium favored the conversion of the acidic form to the lactone form, which was therefore dominant. In their work **[53, 48]** demonstrated that lovastatin in its lactone form, is poorly soluble in water and soluble in organic solvents, while the acidic β-hydroxy form is more soluble in water. Our extractions having been made in ethyl acetate, this would therefore favor the extraction of the lactone form, predominant in the medium under these conditions. While blanching before sun drying produced and increased detection of lovastatin to concentrations of about 1085.2 ± 54.1 µg/g (Figure 4).

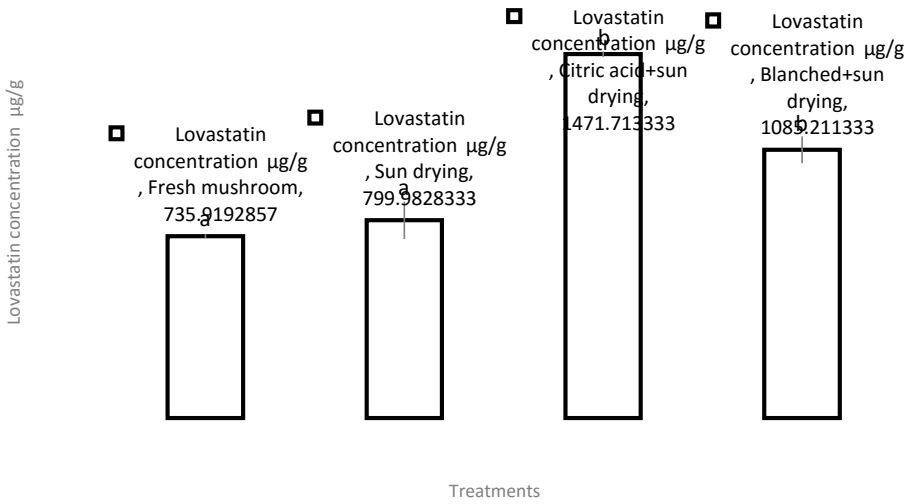

Figure 4:Variation of lovastatin concentration during solar drying according to treatments

3.2. Variation of lovastatin concentration during oven drying according to treatments

From figure 5 and 6 it appears that oven drying at 60 and 70°C without any treatment has no significant effect on the lovastatin concentration. However, citric acid treatment potentiated the detected concentration. Hence acid pre-treatment demonstrated to increase the detection of lovastatin with concentrations of 1216.7 ± 191.6 µg/g and 1335.7 ± 94.0 µg/g dry mushroom respectively at 60 and 70°C compared to 735.9 ± 7.2 µg/g of the control. Giving that the treatment process cannot create new lovastatin, the increased in concentration is related to compound availability during extraction or to the detection method. In fact, we also have to take into account the molar extinction coefficient values of the lactone and acid hydroxy forms of lovastatin. Indeed, **[54]** Seenivasan et al., 2015 in their work performed a regression analysis of the individual forms of lovastatin and the molar extinction coefficients (ε) of the lactone form and acid form of lovastatin obtained were $4.89\times10^4 \pm 21.8$ and $5.99\times10^4 \pm 36$ $M\text{-}1cm^{-1}$, respectively. Using the Beer Lambert equation, we can say that for equal optical density, a shify from total acid form to a total lactone form in a solution will increase the estimated concentration by about 1.22 times without any addition of lovastatin in the medium. Taking into consideration this, increase or reduction in concentrations lower or equal to 1.22 time that of the fresh product was not considered in this work as associated to the transformation process but linked to the spectrophotometer detection method and calculations. Contrary to the result observed during solar drying, blanching followed by oven drying at 60 and 70°C did not result in lovastatin increased detection. This would reflect the fact that, at these temperatures, lovastatin is not degraded and the ratio of the two forms are not changed. Similar results were obtained by **[55]** when lovastatin was treated at 105°C for 4h.On the other hand, oven drying at 80°C regardless of the treatments resulted in a significant decrease in lovastatin concentration in all conditions. However, in opposition with treatments at 60°C and 70°C, blanching pretreatment combined to oven drying at 80°C resulted in the greatest

reduction of lovastatin concentration with regards of the control). This reduction is about 45.4% (401.8 ± 24.8 µg/g of dry mushroom compared to 735.9 ± 7.2 µg/g control (Figure 7). This would suggest that at this temperature lovastatin is hydrolyzed to other by-products that would not absorb at the wavelength used in the work. As mentioned by **[50]** the treatment time effect play a major role in lovastatin stability. They noted that the degradation of statins depended not only on the environmental conditions, but also on the duration of the stress exposure.

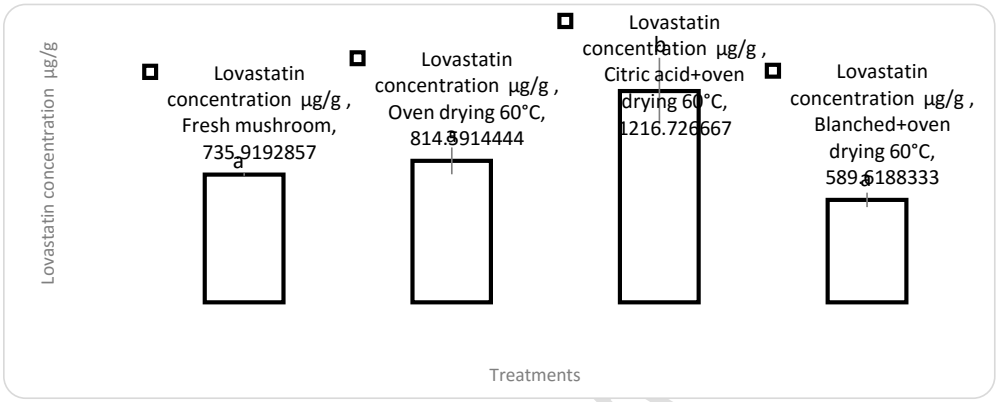

Figure 5: Variation of lovastatin concentration during oven drying at 60°c according to treatments

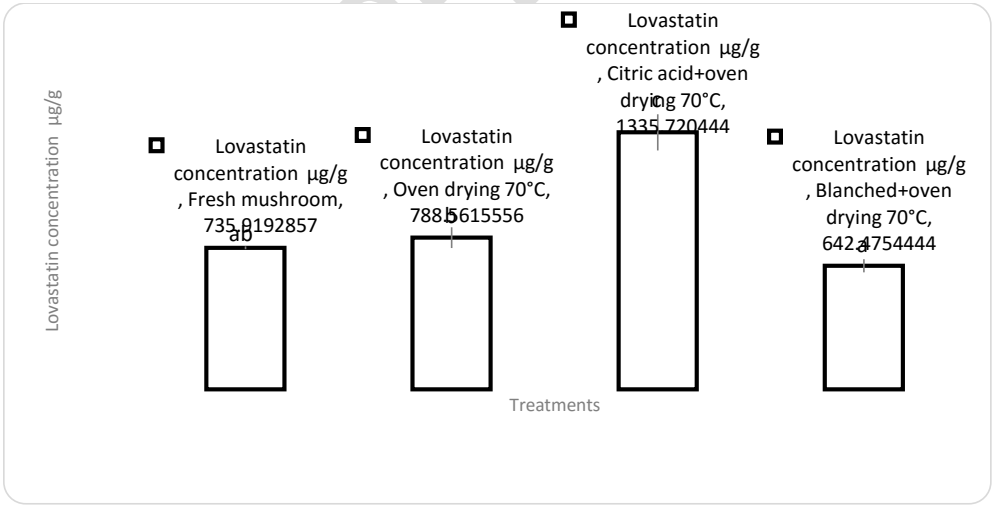

Figure 6: Variation of lovastatin concentration during oven drying at 70°c according to treatments

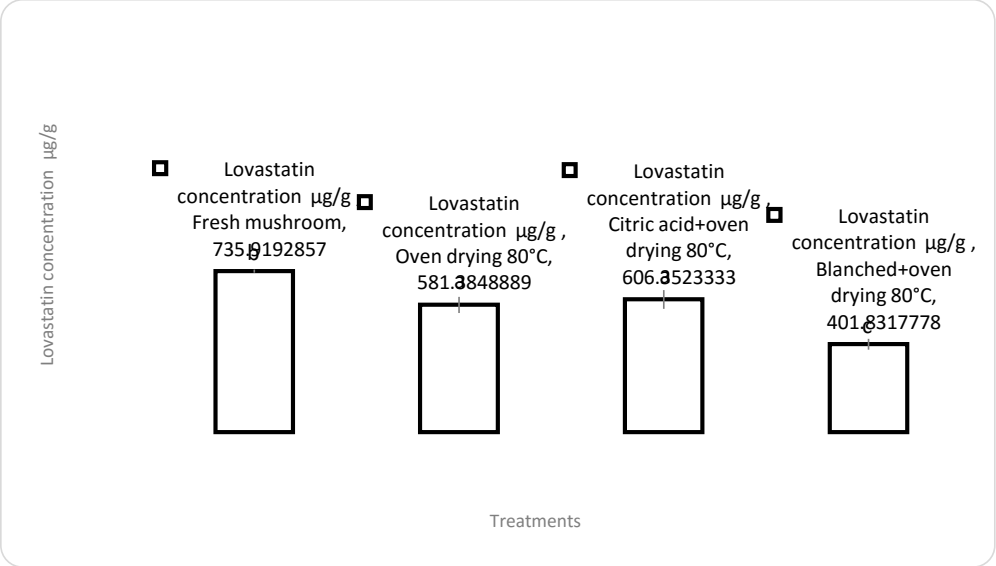

Figure 7:Variation of lovastatin concentration during oven drying at 80°c according to treatments

3.3. Variation of lovastatin concentration in canned mushroom as a function of processing temperature

Canning is a technique by which the mushrooms can be stored for longer periods up to a year at shelf condition. We assessed the effect of different appertization temperatures during canning on the lovastatin concentration. From figure 8, it appears that, blanching do not have a significant effect on lovastatin contain with comparison to the fresh control. This result was also observed after appertization at 100°C. According to **[56],** after neutral hydrolysis of statin the mostly and identified form of lovastatin present in the medium is the hydroxyl acid form which is the same observation with fresh mushroom.On the other hand, the appertization at 110 and 121°C significantly reduced this concentration by 52.2% and 48.9% respectively. This would suggest that at these temperatures lovastatin is hydrolyzed to other by-products that would not absorb at the wavelength used in the work.

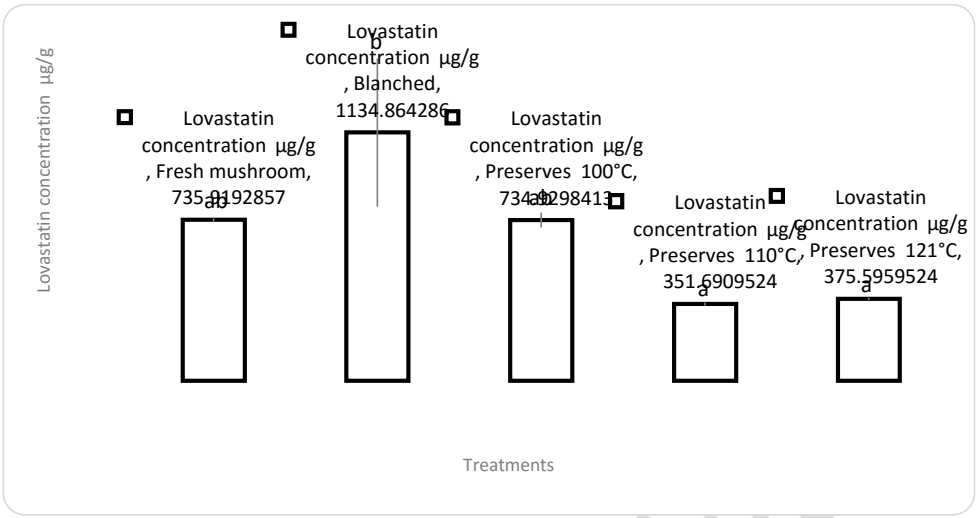

Figure 8: Variation of lovastatin concentration in canned mushroom as a function of processing temperature

3.4. Microbial analysis of preserves

Concerning the microbiological analysis carried out 1 month after the treatments, it appears that, except for the control which presented a microbial load of $6.6*10^7 \pm 1.94$ CFU/ml in total aerobic mesophilic flora, no other condition presented the growth of both total aerobic mesophilic flora and total aerobic spore flora. The Image 1 and 2 below represent the visual aspect of the canned food at different periods of conservation. From this observations we can see that apart from the control which has not been appertized, no visual growth is observable in the different conditions after five months. This reflects the fact that pasteurization and appertization have resulted in deactivation of the microbial flora observed with the control.

Image 1: Evolution of preserves after 1month of conservation

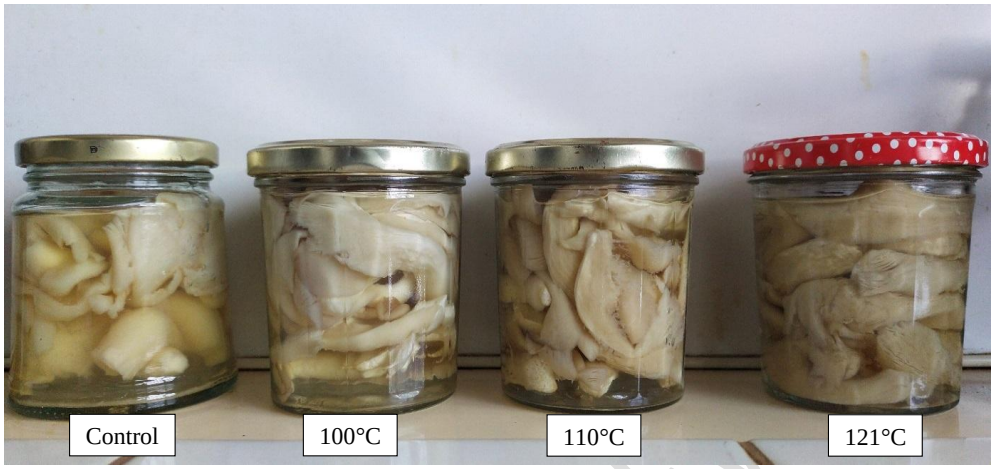

Image 2: Evolution of preserves after five months of conservation

4. Conclusion

One of the fear of the food industry is the loss of nutritional and heath protection compound during food transformation and preservation. In this work, different processes *for Pleurotus ostreatus* storage were assessed with regard to lovastatin degradation. It was observed that application of citric acid and blanching treatment before sun drying or over drying at 60 and 70°C did not caused lovastatin reduction. On the contrary, oven drying at 80°C caused the reduction of this compound irrespective of the type of the pretreatment. Also, during canning, the use of appertization at temperatures higher than 100°C for 15 min caused a significant reduction of lovastatin concentration in comparison to the control, of about 52.2% and 48.9% depending of the pretreatment applie.

Comment [u9]: So, what do you conclude ? What is written here is a brief summary of the findings. But, it is not concluded. In other words, what is learnt from the findings must be drawn at this level.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly used products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

References

[1]Ayeka PA. Potential of Mushroom Compounds as Immunomodulators in Cancer Immunotherapy: A Review. *Evid.-basedComplement. Altern. Med.* 2018;2018:9p. https://doi.org/10.1155/2018/7271509

[2]Food and Agriculture Organization of United Nations (FAO). FAOSTAT Database. Available online: http://www.fao.org/ faostat/en/#data/QC/%0A (accessed on 8 August 2021**).**

[3]Cheung PCK. The nutritional and health benefits of mushrooms. Nutr. Bull. 2010;35(4):292–299. https://doi.org/10.1111/j.1467-3010.2010.01859.x

[4]Guillamon E, García-Lafuente A, Lozano M, Rostagno MA, Villares A, Martínez JA, et al. Edible mushrooms: Role in the prevention of cardiovascular diseases. Fitoterapia. 2010;81(7):715–723. https://doi.org/10.1016/j.fitote.2010.06.005

[5]Kibar B, Akdeniz DH, Pekşen A. The use of corn silage as additive substance in the cultivation of *Pleurotus ostreatus*. SSRG int. j. agric. 2016;2(1):10-17.

[6]Kalac P. A review of chemical composition and nutritional value of wildgrowing and cultivated mushrooms. J. Sci. Food Agric. 2013;93:(2)209–218. https://doi.org/10.12691/ajfn-6-1-4

[7]Valverde ME, Hernandez-Perez T, & Paredes-Lopez, O. Edible mushrooms: Improving human health and promoting quality life. Int. J. Microbiol. 2015; 2015:376–387. https://doi.org/10.1155/2015/376387

[8]Rathore H, Prasad S, & Sharma S. Mushroom nutraceuticals for improved nutrition and better human health: A review. Pharma Nutrition. 2017;5(2):35–46. https://doi.org/10.1016/j.phanu.2017.02.001

[9]Kakon AJ, Choudhury BK, Saha S. Mushroom is an ideal food supplement. J. Dhaka Natl. Med. Coll. Hosp. 2012;18(1):58-62. https://doi.org/10.3329/jdnmch.v18i1.12243

[10]Barros L, Baptista P, Correia DM, Casal S, Oliveira B, Ferreira ICFR. Fatty acid and sugar compositions, and nutritional value of five wild edible mushrooms from Northeast

Portugal. Food Chem. 2007;105 (1): 140-145. https://doi.org/10.1016/j.foodchem.2007.03.052

[11]Nidhiya KA, Sathya E, Nitya M. Extraction and purification of lovastatin from non aflatoxigenic strains of Aspergillus flavus. Int J Bio Pharma Res. 2012;4(12):916- 921

[12]Radha KV, Lakshmanan D. A review: lovastatin production and applications. Asian J Pharma Clincal Res. 2013;6(3):21-26.

[13]Saleem F, Ambreen A, Saleem Y, Naz1 S, Ahmad A, Syed Q. Production and optimization of lovastatin by solid state fermentation using Aspergillus terreus. Global J Sci Res. 2013;1(2):33-41.

[14]Ajdari Z, Ebrahimpour A, Abdul-Manan M, Hamid M, Mohamad R, Ariff AB. Assessment of Monacolin in the fermented products using *Monascus purpureus* FTC5391. Biomed. biotechnol. 2011; Article ID 426168, 9p https://doi.org/10.1155/2011/426168

[15]Kumar A, Singh M, Singh G. Effect of different pretreatments on the quality of mushrooms during solar drying. *J. Food Sci.Technol.* 2013;*50*(1):165–170. https://doi.org/10.1007/s13197-011-0320-5

[16] Fernandes A, Antonio AL, Oliveira MBPP, Martins A, & Ferreira ICFR. Effect of gamma and electron beam irradiation on the physico-chemical and nutritional properties of mushrooms: A review. Food Chem. 2012 ;135(2):641–650.http://dx.doi.org/10.1016/j.foodchem.2012.04.136

[17]Zhang K, Pu Y-Y, & Sun D-W. Recent advances in quality preservation of postharvest mushrooms (Agaricus bisporus): A review. Trends Food Sci Technol. 2018;78(7):72–82. http://dx.doi.org/10.1016/j.tifs.2018.05.012

[18] GirmayZ, W. Gorems, BirhanuG, &**ZewdieS.**Growth and yield performance of *Pleurotus ostreatus* (Jacq. Fr.) Kumm (oyster mushroom) on different substrates, *AMB Express*. 6(2016) 87p. http://dx.doi.org/10.1186/s13568-016-0265-1

[19] Thongklang N, Luangharn T. Testing agricultural wastes for the production of *Pleurotus ostreatus*, Mycophere.2016;7(6):766-772. https://doi.org/10.5943/mycosphere/7/6/6

[20]Friedrich J, Zuzek M, Bencina M, Cimerman A, Strancar A, Radez I. High-performance liquid chromatographic analysis of mevinolin as mevinolinic acid in fermentation broths, J Chromatogr A. 1995;704(2):363–7. https://doi.org/10.1016/0021-9673(95)00096-6

[21]Yang D-J, Hwang LS. Study on the conversion of three natural statins from lactone forms to their corresponding hydroxy acid forms and their determination in Pu-Erh tea. J Chromatogr A. 2006;1119(1-2): 277-84. https://doi.org/10.1016/j.chroma.2005.12.031

[22] Shi-Weng L, Hong-Ping S, &**Yan L.**Rapid determination of lovastatin in the fermentation broth of *Aspergillus terreus* using dual-wavelength UV spectrophotometry. *Pharm Biol*. 2014;52(1):129-135. https://doi.org/10.3109/13880209.2013.833947

[23] Wasser SP, Weis AL. Medicinal properties of substances occurring in higher basidiomycetes mushrooms: Current perspectives. *Int J Med Mushroom.*1999;1(1):31–62. https://doi.org/10.1615/IntJMedMushrooms.v1.i1.30

[24] Wasser SP. Medicinal mushroom as a source of antitumor and immunomodulating polysaccharides. *ApplMicrobiol Biotechnol*.2002; 60(3):258–274.https://doi.org/10.1007/s00253-002-1076-7

[25] Sadler M. Nutritional properties of edible fungi. *Nutr Bull.* 2003;28(3):305–308. https://doi.org/10.1046/j.1467-3010.2003.00354.x

[26] Lindequist U, Niedermeyer TH, Julich WD. The pharmacological potential of mushrooms. *Evid BasedComplement Alternat Med.* 2005;2(3):285–299. https://doi.org/10.1093/ecam/neh107

[27] Cheung PC. Nutritional value and health benefits of mushrooms. In: Cheung PC (ed.). *Mushrooms asFunctional Food.* Hoboken, NJ: John Wiley & Sons, Inc. pp. 2008;71–109.

[28] Patel S, Goyal A. Recent developments in mushrooms as anticancer therapeutics: A review. 3. Biotech. 2012;2(1):1–15.https://doi.org/10.1007/s13205-011-0036-2

[29] Rathee S, Rathee D, Rathee D, Kumar V, Rathee P. Mushrooms as therapeutic agents. Rev Bras Farmacogn. 2012;22(2): 459–474. https://doi.org/10.1590/S0102-695X2011005000195

[30] Manzi P, Gambelli L, Marconi S, Vivanti V, Pizzoferrato L. Nutrients in edible mushrooms: an interspecies comparative study. *Food Chem.* 1999; *65*(4):477-482. https://doi.org/10.1016/S0308-8146(98)00212-X

[31] Longvah T, Deosthale YG. Compositional and nutritional studies on edible wild mushroom from northeast India. *FoodChem.* 1998;*63*(3):331-334. https://doi.org/10.1016/S0308-8146(98)00026-0

[32] Diez V A, Alvarez A. Compositional and nutritional studies on two wild edible mushrooms from northwest Spain. *FoodChem.* 2001;*75*(4):417-422.https://doi.org/10.1016/S0308-8146(01)00229-1

[33] Manzi P, Marconi S, Aguzzi A, Pizzoferrato L. Commercial mushrooms: Nutritional quality and effect of cooking. *FoodChem.* 2004;*84*(2):201-206. https://doi.org/10.1016/S0308-8146(03)00202-4

[34] Manzi P, Aguzzi A, Pizzoferrato L. Nutritional value of mushrooms widely consumed in Italy. *Food Chem.* 2001;*73*(3):321-325. https://doi.org/10.1016/S0308-8146(00)00304-6

[35] Dikeman C.L, Bauer LL, Flickinger EA, Fahey GC. Jr. Effects of stage of maturity and cooking on the chemical composition of select mushroom varieties. *J. Agric. Food Chem.*2005;*53*(4):1130-1138. https://doi.org/10.1021/jf048541l

[36] Fernandes A, Barros L, Barreira JCM, Antonio AL, Oliveira MBPP, Martins A, et al. Effects of different processing technologies on chemical and antioxidant parameters of

Macrolepiota procera wild mushroom. Food Sci. Technol. 2013;54(2):493–499. https://doi.org/10.1016/j.lwt.2013.06.027

[37] Zhang K, Pu Y.-Y, & Sun D.-W. Recent advances in quality preservation of postharvest mushrooms (Agaricus bisporus): A review. Trends Food Sci Technol. 2018;78(7):72–82. https://doi.org/10.1016/j.tifs.2018.05.012

[38]Alarcon J, Aguila S, Arancibia-Avila P, Fuentes O, Zamorano-Ponce E, Hernandez M.
Production and purification of statins from Pleurotus ostreatus (Basidiomycetes) strains. Z Naturforsch C J Biosci. 2003;58(1–2):62–4. https://doi.org/10.1515/znc-2003-1-211

[39]Friedrich J, Zuzek M, Bencina M, Cimerman A, Strancar A, Radez I. High-performance liquid-chromatographic analysis of mevinolin as mevinolinic acid in fermentation broths. J Chromatogr A. 1995;704(2):363–7. https://doi.org/10.1016/0021-9673(95)00096-6

[40]Manzoni M, Rollini M, Bergomi S, Cavazzoni V. Production and purification of statins from Aspergillus terreus strains. Biotechnol Tech 1998;12(7):529–32.https://doi.org/10.1023/a:1008851430560

[41]Morovjan G, Szakacs G, Fekete J. Monitoring of selected metabolites and biotransformation products from fermentation broths by high-performance liquid chromatography. J Chromatogr A 1997;763(1–2):165–72. https://doi.org/10.1016/S0021-9673(96)00875-8

[42]Ajdari Z, Ebrahimpour A, Abdul MM, Hamid M, Mohamad R, Ariff AB. Nutritional requirements for the improvement of growth and sporulation of several strains of Monascus purpureus on solid state cultivation. J Biomed Biotechnol 2011; 2011:1–9. https://doi.org/10.1155/2011/487329.

[43]Chegwin-Angarita C, Jeannette Nieto-Ramirez I, Diaz GJ, Rojas LJ, Sepulveda L, Atehortua L. Evaluation of a method using high performance liquid chromatography with ultraviolet detection for the determination of statins in macromycetes of the genus Pleurotus cultivated by fermentation processes. Talanta. 2013; 116:56–64. https://doi.org/10.1016/j.talanta.2013.04.053.

[44]Jia Z, Zhang X, Zhao Y, Cao X. Effects of divalent metal cations on lovastatin biosynthesis
from Aspergillus terreus in chemically defined medium. World J Microbiol Biotechnol. 2009;25(7):1235–41. https://doi.org/10.1007/s11274-009-0007-5

[45]Kittell J, Borup B, Voladari R, Zahn K. Parallel capillary electrophoresis for the quantitative screening of fermentation broths containing natural products. Metab Eng. 2005;7(1):53–8. https://doi.org/10.1016/j.ymben.2004.09.001.

[46]Lee CL, Wang JJ, Pan TM. Synchronous analysis method for detection of citrinin and the lactone and acid forms of monacolin K in red mold rice. J AOAC Int. 2006;89(3): 669–77. https://doi.org/10.1093/JAOAC/89.3.669

[47]Nigovic B, Sertic M, Mornar A. Simultaneous determination of lovastatin and citrinin in red yeast rice supplements by micellar electrokinetic capillary chromatography. Food Chem. 2013;138(1):531–8. https://doi.org/10.1016/j.foodchem.2012.10.104

[48]Pansuriya RC, Singhal RS. Supercritical fluid extraction of lovastatin from the wheat bran
obtained after solid-state fermentation. Food Technol Biotechnol. 2009; 47(2):159–65.

[49]Yang DJ, Hwang LS. Study on the conversion of three natural statins from lactone forms to their corresponding hydroxy acid forms and their determination in Pu-Erh tea. J Chromatogr A. 2006;1119(1–2):277–84. https://doi.org/10.1016/j.chroma.2005.12.031.

[50]Rini Y, Iyan S, Muchtaridi M. Forced degradation study of statins: a review. *Int J App Pharm*. 2018;10(6):38-42. https://doi.org/10.22159/ijap.2018v10i6.29086

[51]Mulder KCL, Mulinari F, Franco OL, Soares MSF, Magalhães BS, Parachin NS. Lovastatin Production: From Molecular Basis to Industrial Process Optimization. *Biotechnol. Adv.* 2015;*33*(6 Pt 1):648–665.https://doi.org/10.1016/j.biotechadv.2015.04.001.

[52]Lisec B, Radež I, Žilnik LF. Solvent Extraction of Lovastatin from a Fermentation Broth. *Sep. Purif. Technol.* 2012;*96*:187–193. https://doi.org/10.1016/j.seppur.2012.06.006

[53]Sandra JR, Samo K, Borut T, and Franc V. Comparison of CE and HPLC Methods for Determining Lovastatin and Its Oxidation Products after Exposure to an Oxidative Atmosphere. Croat. Chem. Acta. 2003;76(3):263–268. https://hrcak.srce.hr/103177

[54]SeenivasanA, Sathyanarayana N. Gummadi, Tapobrata P and Thomas T. Quantification of Lovastatin Produced by *Monascus purpureus.*Open Biotechnol. J. 2015;*9(1):* 9-16. https://doi.org/10.2174/1874070701509010009

[55]Amit E, Birari. Development and Validation of UVSpectrophotometric Method for Estimationof Simvastatin in Bulk and Solid DosageForm. Int. J. Pharm. Sci. Res. 2015;6(1)185-189.

[56]Silva TD, Oliveira MA, Oliveira RB De, Vianna-Soares CD. Development and validation of a simple and fast HPLC method for determination of lovastatin, pravastatin, and simvastatin. J Chromatogr Sci 2012;50(9):831-8. https://doi.org/10.1093/chromsci/bms079.