



Effect of Fermentation on Selected Vegetable Based Agro by-Products (VBAP) as Alternative Feed Sources

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Abstract – Alternative feed sources using Vegetable Based Agro By-Products (VBAP) could be a pathway for sustainable animal agriculture as well as environmental protection. Though, nutritional contents of these feedstuffs need to be established and improved as viable animal feed sources. Enhancing feed qualities is important such as using fermentation processes which is apt to confirm its potential and popularize it as one of the effective feed processing methods. An experiment using 2 factors such as Factor A (Unfermented VBAP) and Factor B (Fermented VBAP) was carried out to identify and compare the nutrient values of each factor. Fresh VBAP were selected and collected at vegetable farms around Benguet province and La Trinidad Vegetable Trading Post which includes; cabbage (*Brassica oleracea* var. *capitata* L) trimmings, carrot (*Daucus carota* L) tubers, chayote (*Sechium edule*) fruits, lettuce (*Lactuca sativa* L.) leaves, broccoli (*Brassica oleracea* L. var. *Italica* Plenck) trimmings, tomato (*Solanum lycopersicum* L.) fruits, Chinese cabbage/wombok (*Brassica rapa* subsp. *pekinensis*) trimmings and potato (*Solanum tuberosum*) tubers. Proximate analysis was used to measure nutrient composition while spectrophotometer was used to measure minerals contents. The study revealed that fermentation of VBAP significantly decreased pH and moisture and significantly increased % DM, Ash, CP, crude fiber, crude fat, NFE content (p-values of less than 0.01) compared with unfermented VBAP. Mineral content such as calcium and phosphorus has increased positively after fermentation (p-values of less than 0.01). Hence, results of the analysis indicated that fermentation significantly improve the nutrient and mineral contents of the VBAP.

Keywords – Fermentation, Vegetable Based Agro by-Product, Proximate Analysis, Minerals.

I. INTRODUCTION

The increasing population growth worldwide results to growing animal product consumption. Thus, demand for feed products to sustain the animal industry also increases. Addressing the condition becomes a great challenge to animal industries in order to sustain the production and meet the demands. Opportunities for enhancing availability of feedstuffs will include the utilization of feed resources that are available locally and sourcing out alternative feed resources such as waste products that can be used as feed and feed sources. Alternative feed components can become feasible and economical as animal feed sources.

The use of by products as animal feed has direct impact on environmental issues and economy. This includes Vegetable Based Agro By-Products (VBAP) which possesses feeding value required by animals for sustainable production. VBAP are materials derived from non-marketable vegetable fragments after harvest. Converting these agricultural products that are not viable to human consumption into animal feed will enhance sustainability of animal production as well as mitigating environmental concerns due to lessening of waste.



Agricultural by products such as potato fiber co-product contains 55% of total dietary fiber, 29% starch, 4% crude protein, and 2% acid-hydrolyzed fat (Panasevich et al., 2013). Tomato pomace product has a chemical contains of 17-22 % DM protein, 10-15 % DM fat up to 20 % depending on the ratio of tomato seed, 50-70% insoluble fibers in neutral detergent (NDF), 39-60% ADF, and lignin is 20-30 % of DM (Jamehshooran et al., 2022). On the other hand, cabbage nutrient composition has 7.0% DM, Crude protein 16.6%, ADF 15.8%, NDF 20.0%, Sulfur 0.70%, TDN 74.0%, Net energy lactation (Mcal/lb) 0.77 (Binversie and Miller, 2013). Fresh cabbage nutrient contents of g/100g have moisture (69.365), protein (1.1), fat (0.225), fiber (2.63), ash (1.39) (Tanko et al., 2018). Carrot peels chemical analysis has contents of moisture (%) 7.46 ± 0.35 , Ash (%) 11.2 ± 0.70 , fiber (%) 17.05 ± 0.59 , fat (%) 3.48 ± 0.0004 , protein (%) 4.47 ± 0.14 , carbohydrates (%) 56.0 ± 0.60 , pH 5.75 ± 0.037 (Ashraf, 2015). In broccoli stems, 9.41% (DM), 89.3g/100g(OM), 23.2g/100g (CP), 2.91(EE), 33.4 sugars, 22.3 (NDF), 15.0 (ADF), 1.46 (lignin), 7.27 hemicellulose, 31.3 (NSC), 6.49 (lignin), 5.77 (NDICP) while broccoli florets 13.9% (DM), 91.8g/100g (OM) 30.8 (CP), 6.15 (EE), 19.6 sugars, 23.6 (NDF), 12.9 (ADF), 0.84 lignin, 10.7 hemicellulose, 40.9 (NSC) AND 9.94 (NDICP) (de Evan et al., 2020). Analysis of fresh tomato chemical contents hold moisture (68.03 ± 3.05), ash (0.86 ± 1.15), crude fiber (1.78 ± 0.13), crude fat (2.36 ± 0.67) and CHO (9.94 ± 3.41) (Ahmed, 2020).

Fermentation is a process that changes the biochemical and nutritional value in relation to the original state through the involvement of microorganism interacting with the enzymes of the raw ingredients. Microorganisms improve the physiochemical aspects and the nutritional content and could expand the shelf life and safety of the raw ingredients through fermentation (Ayed et al., 2020). In addition, microorganisms involved in the fermentation process deliver unique process such as biochemical and physical changes resulting to food stability of fermented foods (Sharma et al., 2020).

Fermented feed has been widely studied for the purpose of effective utilization of feedstuff and to lessen application of in-feed antibiotics. Fermentation of feed through microorganisms can reduce anti-nutritional aspects and improve nutritional value (Qui et al., 2020). Lactic acid bacteria (LAB) fermentation improves nutritional value and organoleptic features of fermented products. This microorganism produces different antimicrobial compounds and convert substance that are indigestible into digestible products (Ayed et al., 2020). These microorganisms are used to produce various fermented products from raw materials including vegetable, animal milk and fermented feed silage. LAB place a great impact in the fermented food products in terms of nutritional, sensorial, technological, and functional features due to its metabolic activity with other substrates. LAB fermentation used as natural preservation of raw ingredient and it is also responsible for bioconversion of the carbohydrates in lactic acid, tearing minor quantities of other organic acids that decrease the level of pH (Sabater et al., 2020).

Likewise, solid-state fermented feed by using natural or artificially added microorganisms in a controlled environment can be used as alternative livestock feed antibiotics (Yang et al., 2021). Fruit and vegetable by-products and waste that undergo solid-state fermentation are enhanced with protein raw materials, though the sugar content decreased and a rise in NDICP and fiber content (Ibarruri et al., 2021).

II. MATERIALS AND METHODS

A. Selection and Collection of the VBAP



The VBAP were selected and collected at vegetable farms around Benguet province and La Trinidad Vegetable Trading Post which includes; cabbage (*Brassica oleracea var. capitata L*) trimmings, carrot (*Daucus carota L*) tubers, chayote (*Sechium edule*), lettuce (*Lactuca sativa L.*), broccoli (*Brassica oleracea L. var. Italica Plenck*), tomato (*Solanum lycopersicum L.*) fruits, Chinese cabbage/wombok (*Brassica rapa subsp. pekinensis*) and potato (*Solanum tuberosum*) tubers.

B. Preparation of Unfermented VBAP Prior to Analysis

Samples of VBAP collected were washed in a clean water in order to eliminate inessential materials, and were chopped to approximately 1-3 cm. Samples of each VBAP were weighed 250g per sample with 3 replicates and were delivered to LQCC-Bulacan for Proximate and mineral analysis.

C. Fermentation Procedure of VBAP

The prepared samples were chopped to less than 3cm and were weighed individually per VBAP then added with 15% of molasses based from its total weight. Weighted sample with molasses were then placed in an empty high-density polyethylene plastic jar installed with airlock fermenter. VBAP samples were placed and compacted inside the container to minimize air spaces. After filling, containers are sealed tightly to prevent oxygen from entering inside the container. Filled and sealed containers were stored in a cool dark area for 20 days. Temperature ranges from 16 degrees Celsius to 22 degrees Celsius.

D. Proximate Analysis

Unfermented VBAP were prepared and placed in a zip lock with 3 replicates per VBAP and were brought to laboratory for proximate analysis. Fermented VBAP were submitted to the laboratory after 20 days fermentation. Nutrient contents such as Moisture, Dry matter (DM), Ash, crude protein (CP), crude fat, crude fiber (CF) and Nitrogen Free Extract (NFE) following the AOAC International guidelines (2005) content and mineral contents such as calcium and phosphorus were analyzed per VBAP samples at Lipa Quality Control Center Inc. (LQCCI) North, Gov F Halili Ave, Barangay Turo, Bocaue, Bulacan.

E. pH Determination of Unfermented and Fermented VBAP

The pH of the unfermented and fermented VBAP was recorded using digital pen type portable pH meter.

F. Experimental Design and Statistical Analysis

This study was conducted in an 8x2 factorial in CRD replicated 3 times with different unfermented VBAP as Factor A namely: cabbage trimmings, carrot tubers, sayote, lettuce, broccoli, tomato fruits, Chinese cabbage/wombok and potato tubers and fermented VBAP as Factor B (with 15% molasses). Data was analyzed using SPSS version 21. Analysis of variance (ANOVA) and statistically significant parameters were compared using Least Significant Difference (LSD).

III. RESULTS AND DISCUSSION

A. pH Value of Unfermented and Fermented VBAP

Analysis revealed highly significant differences on the pH value of VBAP when compared according to fermentation with computed p-values of less than 0.01 as presented in Table 1. Specifically, unfermented VBAP



had higher pH content than fermented VBAP with mean values of 5.53 and 3.17, respectively. Numbers shows that all fermented VBAP has reduced pH value after fermentation compared with unfermented VBAP. This finding simply implies that fermentation significantly affect the pH value of VBAP. Meanwhile, VBAP with highest pH value is unfermented chayote followed by unfermented broccoli and unfermented carrot. Further, VBAP with lowest pH value are fermented chayote and fermented Chinese cabbage.

Results confirm the same result with the study of Adegunloye and Oparinde (2017) that the pH value of irish potato peels declined significantly ($P \leq 0.05$) after fermentation while Vatansever et al. (2017) reported that carrot have decreased pH value after 10 days fermentation with 3.99 ± 0.04 .

Table 1. pH Value of Unfermented and Fermented VBAP.

VBAP	Unfermented	Fermented
Broccoli	6.33	3.30
Cabbage	5.05	3.32
Carrot	5.79	3.10
Chayote	6.41	3.02
Chinese Cabbage	5.57	3.01
Lettuce	5.61	3.10
Potato	5.60	3.31
Tomato	3.91	3.22
Mean	5.53	3.17

Reduction of pH is a result of Lactic Acid Bacteria (LAB) activity during fermentation. LAB is responsible for lactic acid fermentation and requires reduced pH level during food fermentation for their growth and prevent growth of undesirable microbes like yeasts, molds and pathogenic bacteria and to sustain level of pH ($pH < 4.6$) and guarantee the safety of food (Vatansever et al., 2017).

B. Proximate Analysis Content of Unfermented and Fermented VBAP

Table 2 shows the proximate analysis content of fermented and unfermented VBAP with computed p-values of less than 0.01. Result indicates that broccoli has higher moisture content after fermentation but has lower DM, ash, CP, crude fiber, crude fat and NFE compared with unfermented broccoli. Cabbage has lower moisture content and higher DM, ash, CP, crude fiber, crude fat and NFE after fermentation compared with unfermented. In carrot, moisture content and crude fat has lesser amount after fermentation while greater value on DM, ash, CP, and NFE after fermentation but crude fiber has same value of booth fermented and unfermented. Moisture and crude fiber content of chayote decreased after fermentation while higher amount in DM, ash, CP, crude fat and NFE content compared with unfermented one. Fermented Chinese cabbage has lower moisture content and higher DM, ash, CP, crude fiber, crude fat and NFE than unfermented Chinese cabbage. Meanwhile, lettuce has lower moisture content after fermentation and higher DM, ash, CP, crude fiber, crude fat and NFE content than unfermented. Fermented potato also has higher DM, ash, CP, crude fiber, crude fat and NFE content but lower moisture content compared with unfermented potato. Lastly, tomato has decreased moisture content and increased DM, ash, CP, crude fiber, crude fat and NFE after fermentation.



On the other hand, fermented broccoli has the highest moisture content followed by unfermented potato then unfermented lettuce while unfermented and fermented potato has the lowest moisture content. VBAP with highest dry matter content are fermented potato, unfermented potato and unfermented broccoli while lowest in unfermented tomato and fermented broccoli. VBAP with highest ash content are unfermented broccoli, fermented Chinese cabbage and fermented potato while unfermented tomato and fermented broccoli has the lowest ash content. For crude protein content, fermented potato, fermented cabbage and unfermented broccoli has the highest amount while lowest content in unfermented chayote and fermented broccoli. Moreover, VBAP with highest crude fiber content is unfermented broccoli followed by fermented potato and fermented cabbage while fermented chayote and fermented broccoli have the lowest crude fiber content. For crude fat content, unfermented broccoli, fermented tomato and fermented Chinese cabbage got the highest value while unfermented potato and fermented broccoli hold the lowest crude fat content. Finally, VBAP with highest NFE content are fermented potato, unfermented potato and fermented chayote while lowest NFE content are unfermented lettuce and fermented broccoli.

Finding of Islam et al. (2018) presented lower crude fiber content of cabbage with 0.27% and lower percentage amount of unfermented chayote with 93.27% moisture, 0.30% ash, 0.15% crude fat while higher in CP (0.84%) compared with the findings in this study.

Furthermore, Tanko et al., (2018) reported lower moisture content (69.365%), ash (1.1035%), CP (1.1%), crude fat (0.225%) of unfermented cabbage and fermented cabbage moisture (90.56%), CP (1.3%), crude fat (0.23%) while higher ash (1.39%), crude fiber (2.63%) of unfermented cabbage and crude fiber (2.61%) of fermented cabbage.

Sun et al. (2017) discussed lower content of DM (13.0%), ash (0.5%), CP (0.95%) of unfermented potato while higher content in crude fat (1.24%) content of fermented potato. Furthermore, Yang et al. (2021) presented higher value in DM (9.97%) of unfermented cabbage but lower DM (3.26%) content of unfermented potato. Also, de Evan et al., (2018) reported lower DM (5.64%) of unfermented cabbage compared with the results of this study.

Adegunloye and Oparinde (2017) discussed that the pH value of sweet potato and irish potato significantly reduced ($P \leq 0.05$) while increase in the moisture, ash, fat and protein content of both peels, though the crude fiber and carbohydrate content has decreased after fermentation.

Table 2. Proximate Analysis Content of Unfermented and Fermented VBAP.

		Broccoli	Cabbage	Carrot	Chayote	Chinese Cabbage	Lettuce	Potato	Tomato
Moisture	un	86.39	93.30	91.11	95.03	94.73	95.86	85.37	96.74
	f	99.11	90.56	88.43	87.76	90.06	91.09	76.09	89.58
DM	un	13.61	6.70	8.89	4.97	5.27	4.14	14.63	3.26
	f	0.89	9.44	11.57	12.24	9.94	8.91	23.91	10.42
Ash	un	1.67	0.78	1.14	0.43	0.94	1.06	0.93	0.39
	f	0.07	1.27	1.48	1.31	1.57	1.27	1.53	1.14
CP	un	1.96	1.54	1.08	0.60	1.60	0.82	1.82	0.71



		Broccoli	Cabbage	Carrot	Chayote	Chinese Cabbage	Lettuce	Potato	Tomato
	f	0.11	1.97	1.48	1.40	1.82	1.73	2.74	1.37
Crude Fiber	un	2.09	0.76	0.92	0.49	0.71	0.61	0.41	0.44
	f	0.08	1.12	0.92	0.33	0.79	0.87	1.77	0.89
Crude Fat	un	0.69	0.27	0.29	0.17	0.17	0.27	0.16	0.19
	f	0.02	0.30	0.25	0.27	0.42	0.36	0.35	0.44
NFE	un	7.19	3.35	5.46	3.28	1.85	1.39	11.31	1.53
	f	0.61	4.77	7.45	8.95	5.34	4.68	17.51	6.56

*Note: un-unfermented; f- fermented.

Variation among proximate analysis content of unfermented and fermented VBAP might due to diverse kinds of varieties, physical characteristics, growing conditions, storing, process of fermentation and other factors (Jansone and Kampuse, 2019).

The improved nutritional value in fermented VBAP compared with the unfermented VBAP is a result from fermenting microorganisms present in the product. Fermentation improves the food nutritional quality through enhancing the density of nutrients and swelling the quantity and bioavailability of nutrients. Increasing the bioavailability and amount of nutrients from food may be attained by the degradation of anti-nutritional aspects, producing agents for absorption, and pre-digestion of different components of food. Lactic acid fermentation enhances the accessibility of some micronutrients and limiting amino acids and protein solubility (Sharma et al. 2020).

C. Calcium (Ca) and Phosphorus (P) Content of Unfermented and Fermented VBAP

Analysis revealed highly significant differences on the calcium and phosphorus content of VBAP when compared according to fermentation with computed p-values of less than 0.01 as presented in Table 3. Results simply implies that fermentation significantly affect the calcium and phosphorus content of VBAP.

Cabbage, carrot, chayote, Chinese cabbage, lettuce, potato and tomato have increased in calcium and phosphorus content after fermentation while broccoli decreased in calcium and phosphorus content after fermentation.

Definitely, unfermented broccoli had the highest calcium content with value of 0.26. This was followed by fermented potato and fermented Chinese cabbage with values of 0.13 and 0.12, respectively. On the other hand, unfermented chayote, unfermented tomato and fermented broccoli had the lowest calcium content with average values between 0.02 to 0.01.

Table 3. Calcium and Phosphorus Content of Unfermented and Fermented VBAP.

VBAP	Ca		p	
	Unfermented	Fermented	Unfermented	Fermented
Broccoli	0.26	0.01	0.05	0.00
Cabbage	0.05	0.11	0.04	0.05



VBAP	Ca		p	
Carrot	0.04	0.11	0.05	0.07
Chayote	0.02	0.11	0.02	0.04
Chinese Cabbage	0.07	0.12	0.05	0.06
Lettuce	0.04	0.11	0.02	0.04
Potato	0.04	0.13	0.04	0.07
Tomato	0.02	0.08	0.02	0.03

Unfermented potato has 0.04% calcium content higher than 0.006% reported by Sun et al. (2017). Likewise, unfermented potato has 0.04% P content higher than 0.011% reported by Sun et al. (2017).

Results from the study revealed that fermentation influenced the mineral content of the VBAP. Mainly, vegetables that undergone the process of fermentation have higher bioavailable nutrients such as minerals compared to unfermented VBAP. That situation is result from a decrease in anti-nutritional elements like tannins and phytates. The amount of certain microelements in fermented vegetables is characterized by various variations which could decrease or increases. Though, bioavailability of nutrients in fermented vegetables is always higher compared to fresh vegetables (Knez et al., 2023).

IV. CONCLUSION

The goal of this research was to identify the nutritional contents of fermented compared with unfermented VBAP. The results revealed that VBAP contains nutrient needed by the animals as shown in the gathered data and can be used as alternative feeds for animal production. Likewise, fermentation decreased the pH and moisture content of VBAP. Further, it appears to improve the nutrient content and mineral content of VBAP as revealed in the analysis results such as dry matter, ash, crude protein, crude fiber, crude fat, nitrogen free extract and mineral content analysis such as calcium and phosphorus. Therefore, animal nutritionist, farmers and practitioners could use fermentation as other way of improving the nutritional value of VBAP. Continuing research on nutrient analysis, fermentation, and practical application of VBAP should be the concentration on future study.

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REFERENCES

- [1] Abubakar, M., Iqbal, A., Kabir, A. & Manzoor, S. (2018). Ruminants-The Husbandry, Economics and Health Aspects. Intech Open. DOI: 10.5772/intechpen.76064
- [2] Adegunloye, D.V. & Oparinde, T.C. (2017). Effects of Fermentation on the Proximate Composition of Irish (*Solanum tuberosum*) and Sweet Potato (*Ipomoea batatas*) Peels. *Advances in Microbiology*, 2017, 7, 565-574 <http://www.scirp.org/journal/aim> ISSN Online: 2165-3410 ISSN Print: 2165-3402
- [3] Ahmed, M.J., Iya, I.R.,1 and Dogara, M.F. (2020). Proximate, Mineral and Vitamin Content of Flesh, Blanched and Dried Tomatoes (*Lycopersicon esculentum*). *Asian Food Science Journal* 18(4): 11-18, 2020; Article no. AFSJ.55829 ISSN: 2581-7752.
- [4] Ashraf, H. (2015). Biosynthesis, partial purification and characterization of invertase through carrot (*Daucus carota* l.) peels. *Academia Journal of Biotechnology* 3(2): 015-025, August 2015 DOI: 10.15413/ajb.2014.0113 ISSN 2315-7747©2015 Academia Publishing.
- [5] Ayed, L, M'hir, S., and Hamdi, M. (2020). Microbiological, Biochemical, and Functional Aspects of Fermented Vegetable and Fruit

- Beverages. Journal of Chemistry Volume 2020, Article ID 5790432, 12 pages <https://doi.org/10.1155/2020/5790432>
- [6] Binversie, L. and Miller, Z., (2013). Feeding Cabbage Waste. University of Wisconsin-Madison/Extension.
- [7] De Evan, T., Vintimilla, A., Marcos, C.N., Ranilla, M.J. and Carro, M.D. (2019). Evaluation of Brassica Vegetables as Potential Feed for Ruminants. *Animals* 2019, 9, 588; doi: 10.3390/ani9090588 www.mdpi.com/journal/animals
- [8] Ibaruri, J., Goiri, I., Cebrián, M., Garcia-Rodríguez, A. (2021). Solid State Fermentation as a Tool to Stabilize and Improve Nutritive Value of Fruit and Vegetable Discards: Effect on Nutritional Composition, in Vitro Ruminal Fermentation and Organic Matter Digestibility. *Animals* 2021, 11, 1653. <https://doi.org/10.3390/ani11061653>
- [9] Islam, S., Kumar, A., Dash, K.K., Alom, S. (2018). Physicochemical analysis and nutritional properties of fresh, osmo-dehydrated and dried chayote (*Sechium edule* L.). *Journal of Postharvest Technology*, 6 (2): 49-56.
- [10] Jamehshooran, E.G., Khorshidi, K.J. and Kouhsar, J.B. (2022). Chemical composition, aerobic stability and fermentation pattern of tomato pomace and pumpkin waste silage using fibrolytic enzymes and lactic acid bacteria. *International Journal of Recycling of Organic Waste in Agriculture* (2022)11: 47-59 Doi: 10.30486/IJROWA.2021.1923435.12
- [11] Jansone, L., & Kampuse, S. (2019). Comparison of Chemical Composition of Fresh and Fermented Cabbage Juice. *FOODBALT* 2019. DOI: 10.22616/FoodBalt.2019.028
- [12] Knez, E, Kadac-Czapska, K., Grembecka, M. (2023). Effect of Fermentation on the Nutritional Quality of the Selected Vegetables and Legumes and their Health Effects. *Life (Basel)*. 2023 Feb 27; 13(3): 655. doi: 10.3390/life13030655. PMID: 36983811; PMCID: PMC10051273.
- [13] Kiczorowski, P., Kiczorowska, B., Samolińska, W., Szmigielski, M. & Winiarska-Mieczan, A. (2022). Effect of fermentation of chosen vegetables on the nutrient, mineral, and biocomponent profile in human and animal nutrition. *Scientific Reports |* (2022) 12:13422 | <https://doi.org/10.1038/s41598-022-17782-z>
- [14] Panasevich, M.R., Rossoni Serao, M.C., de Godoy, M.R.C., Swanson, K.S., Guerin-Deremaux, L., Lynch, G.L., Wils, D., Fahey, G.C. Jr., and Dilger, R.N (2013). Potato fiber as a dietary fiber source in dog foods. *J ANIM SCI* 2013, 91:5344-5352. doi: 10.2527/jas.2013-6 842.<http://www.journalofanimalscience.org/content/91/11/5344>
- [15] Qiu, Y., Li, K., Zhao, X., Liu, S., Wang, L., Yang, X. and Jiang, Z. (2020). Fermented Feed Modulates Meat Quality and Promotes the Growth of *Longissimus Thoracis* of Late-Finishing Pigs. *Animals* 2020, 10, 1682; doi:10.3390/ani10091682 www.mdpi.com/journal/animals
- [16] Sabater C, Ruiz L, Delgado S, Ruas-Madiedo P and Margolles A (2020). Valorization of Vegetable Food Waste and By-Products Through Fermentation Processes. *Front. Microbiol.* 11:581997. doi: 10.3389/fmicb.2020.581997
- [17] Sharma, R., Garg, P., Kumar, P., Bhatia, SK. and Kulshrestha, S. (2020). Microbial Fermentation and Its Role in Quality Improvement of Fermented Foods. *Fermentation* 2020, 6, 106; doi:10.3390/fermentation6040106 www.mdpi.com/journal/fermentation
- [18] Suna, M., Wanga, B., Liua, X., Lib, L. & Yue, C. (2017). Research on Microbial Fermentation of Potato Residue for Animal Feed. *Chemical Engineering Transactions*, 59, 787-792 DOI:10.3303/CET1759132
- [19] Tanko, O.O., Gberikon, G.M., Azua. E.T. (2018). Proximate Composition and Essential Amino Acids Profile of Fermenting Cabbage Leaves to Sauerkraut using Starter Cultures and Spontaneous Fermentation. *International Journal of Science and Research (IJSR)* ISSN: 2319-7064 Impact Factor (2018): 7.426
- [20] Vatanserver, S., Vegi, A., Garden-Robinson, J. & Hall, C.A. III (2017). The effect of fermentation on the Physicochemical characteristics of dry-salted vegetables. *Journal of Food Research*; Vol. 6, No. 5; 2017 ISSN 1927-0887 E-ISSN 1927-0895 Published by Canadian Center of Science and Education.
- [21] Yang, Kaili, Qing, Yiqing, Yu, Qifang, Tang, Xiaopeng, Chen, Gang, Fang, Rejun Fang and Liu, Hu. (2021). By-Product Feeds: Current Understanding and Future Perspectives. *Agriculture* 2021, 11, 207. <https://doi.org/10.3390/agriculture11030207>

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