Rev. Bras. Saúde Prod. Anim., Salvador, v.18, n.4, p.594-603 out./dez., 2017 ISSN 1519 9940
http://mc04.manuscriptcentral.com/rbspa-scielo http://dx.doi.org/10.1590/S1519-99402017000400010

Composting for valuation of marine fish waste

Compostagem na valoração de resíduos de pescado marinho

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SUMMARY

This trial evaluated the composting for valuation of marine fish waste. The study was carried out in a composting cell (1.10m length, 1.50m width, 1.20m height, and 2.50m headroom), which received a mixture of marine fish waste (skin and fin) and reused wood shavings at a 7:3 proportion. The efficiency of the composting process was evaluated through analysis of biomass temperature, moisture, pH, ash, compost mineralization index, carbon/nitrogen ratio, total organic matter, total organic carbon and total nitrogen. Data were tested by analysis of variance and polynomial regression, and the means compared by Tukey's test at 5%. The results showed that composting is an efficient alternative for the valuation of fish residues. The compost complies with the Brazilian Standards (Normative Instruction 25/2009 of the Brazilian Ministry of Agriculture, Livestock and Food Supply). The C/N ratio lower than 15/1 combined with the high moisture content of the substrates inhibit the increase in the biomass temperature. The wood shavings reused for three consecutive times provide nitrogen. The addition of water to the composting process should be suppressed when using the proportion of 7kg fish waste and 3kg reused wood shavings.

Keywords: compost, environment, fish, water resources

RESUMO

Objetivou-se avaliar a compostagem na valoração de resíduos de pescado marinho da Colônia de Pescadores Z-3. O experimento foi realizado em uma composteira em célula nas dimensões 1,10 m de comprimento, 1,50 m de largura e 1,20 m de altura, com pé direito de 2,50 m, que recebeu a mistura de resíduos de pescado marinho (pele e barbatana) e maravalha de pinus reutilizada na proporção 7:3. A eficiência do processo de compostagem foi avaliada através das análises de temperatura da biomassa, umidade, pH, cinzas, índice de mineralização do composto, relação carbono/nitrogênio e os teores totais de matéria orgânica, carbono orgânico e nitrogênio. Os dados foram submetidos á análise de variância e regressão e as médias comparadas pelo teste de Tukey a 5%. Os resultados demonstraram que a compostagem é uma alternativa eficiente para a valoração dos resíduos de pescado da Colônia de Pescadores Z-3. O composto produzido atende a Instrução Normativa no. 25/2009 do Ministério da Agricultura, Pecuária e Abastecimento, para ser comercializado como fertilizante orgânico. A relação C/N menor que 15/1 associada á alta umidade da mistura dos substratos inibem o aumento da temperatura da biomassa. A maravalha reutilizada por três vezes consecutivas serve como fonte de nitrogênio. A adição de água ao processo de compostagem deve ser suprimida quando for utilizada a proporção 7 kg de resíduos de pescado para 3 kg de maravalha reutilizada.

Palavras-chave: composto, meio ambiente, peixe, recursos hídricos

INTRODUCTION

The world demand for fish has undergone a significant increase in the last decades, mainly due to the population growth and the search of consumers for healthier foods (BRABO et al., 2016).

However, the consumer preference for fish fillet causes approximately half of the fish to be sent to the filleting process, which increases the volume of waste generated, reaching 65% live weight. These residues are mainly viscera, tail, spine, fin, scales and meat remains.

Due to the large volume produced, improper waste disposal practices, such as discharge into water courses, have contributed to environmental degradation for some time, further accentuating the difficulties faced by fishermen. The significant increase in the concentration of phosphorus and nitrogen, as well as the decrease in the concentration of dissolved oxygen are situations that can be found in the region through the eutrophication process and fish mortality.

In this sense, composting is an important tool for transforming fish waste into organic fertilizers, and can ensure environmental sustainability in fishing communities. Organic compounds are easily mineralized and metabolized by different populations of aerobic mesophilic, thermotolerant and thermophilic microorganisms that produce carbon dioxide, ammonia, water, organic acids and heat (LÓPEZ-GONZÁLEZ et al., 2015).

However, Valente et al. (2009) point out that the efficiency of the composting process is directly related to the combination of factors such as humidity, oxygen rate, carbon/nitrogen ratio and porosity, which provide optimal conditions for different populations of aerobic microorganisms to grow and develop in the biomass. Lopes et al. (2015) state that the product obtained has a high agronomic value and can be used as soil broker or organic fertilizer. In the meantime, Sanes et al. (2015) observed that complementary studies have to be conducted to better understand the fish waste composting process, as well as the qualification of the product obtained.

In this context, this study aimed to evaluate the composting process in the valuation of marine fish waste.

MATERIAL AND METHODS

The study was conducted at the Composting Sector of the Laboratory of Animal Science Teaching and Experimentation (LEEZO) Professor Doutor Renato Rodrigues Peixoto, Department of Animal Sciences, Faculty of Agronomy Eliseu Maciel (FAEM), Federal University of Pelotas (UFPEL), located in the municipality of Capão do Leão, State of Rio Grande do Sul.

The composting process was performed in a masonry cell, waterproofed, 1.10m length, 1.50m width, 1.20m height, and 2.50m headroom. The upper part of the cell was open and protected by a screened structure and its front had movable wood boards to facilitate filling with the organic waste up to the height of 1.00 m, which were subjected to composting for 60 days.

The cell was supplied with fish waste (skin and fin not crushed) from marine activity and pine wood shavings (*Pinus* spp.) reused in three other experiments with composting of fish waste, carcasses of dogs and dairy cattle at the 7: 3 mass ratio. The proportions between the raw materials were based on studies by Valente et al. (2014a), who used wood shavings in the degradation of fish waste at the 3: 1 ratio and concluded that a larger amount of protein source could have been used. The height used for the structuring agent layer was 0.10 m, following the methodology of Paiva (2004), determined by weighing and defined by measurements with a measuring tape, thus obtaining 27.4 kg per layer.

The proportions of fish waste were laid on layers, respecting the distance of 0.10 m between them, from the walls and the front of the composting cell. Thus, 63 kg of marine fish waste per layer were arranged. The organic waste occupied the height of 1.00 m, totaling 471.40 kg. The water was added with the aid of a graduated vessel, at a proportion of 20% of the mass of the wood shavings layer, which corresponded to 5.5 L per layer.

Five numbered wooden stakes were placed at a distance of 0.20 m between them and from the sidewall of the composting cell in order to demarcate each point of collection and gauging. The compost mass temperature was measured daily, at 9:30 h, using a digital thermometer (± 0.1ºC DIGITECH) with a metal shaft of 0.12 m. Analyses of the chemical composition of the composting mass were carried out in triplicate, and the first sample corresponded to the initial substrates reused wood shavings and fish waste (skin and fin) (Table 1). Samples were dried in a forced air circulation oven at 65 ºC. The grinding of the material was carried out in a mill Marconi®, model MA 048. The remaining samples were collected at the five points in the following five periods: 15, 30, 45 and 60 days, corresponding to T1, T2, T3 and T4.

Table 1. Chemical composition of the substrates used in the composting process

Chemical composition	Substrates	
	Reused wood shavings	Skin/Fins
pH	5.3 ± 0.09	6.5 ± 0.07
Moisture (%)	62.0 ± 0.08	79.9 ± 0.09
Total organic matter (%)	77.5 ± 0.02	85.9 ± 0.81
Ash (%)	22.5 ± 0.02	14.1 ± 0.81
Total organic carbon (%)	43.1 ± 0.04	47.7 ± 0.06
Total nitrogen (%)	2.9 ± 0.03	12.5 ± 0.04
Carbon/nitrogen ratio	14.8 ± 0.07	3.8 ± 0.09

Mean values of three replicates.

In the Animal Nutrition Laboratory of DZ/FAEM/UFPEL, samples were analyzed for moisture, pH, total nitrogen, according to the methodology described by Silva & Queiroz (2004) and also the analyses of total organic matter, ash content and total organic carbon, according to the methodology described by Kiehl (1985). The C/N ratio was obtained by the equation C/N = %C ÷ %N, where %C = percentage of total organic carbon in the sample; %N = percentage of total nitrogen in the sample, as described by Tedesco et al. (1995). The calculation of the mineralization index of the compost

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was obtained by the equation IMC = %CZ ÷ %C, where %CZ = percentage of ash in the sample; %C = percentage of total organic carbon in the sample, according to Drozd et al. (1997).

For the statistical analysis, a completely randomized design was used, with four treatments and five replications. Data were tested by analysis of variance by General Linear Models (GLM) of the software Statistical Analysis System version 9.1 (SAS, 2003) and regression, and the means were compared by Tukey's test at a significance level of 5%.

RESULTS AND DISCUSSION

In Figure 1, on day zero, the average temperature of the biomass was 15.3ºC, characterizing the cryophilic phase of the composting process. Valente et al. (2014a) investigated the composting of the mixture of freshwater fish filleting waste (head, carcass and viscera not crushed) and pine wood shavings at the 1: 3 mass ratio, respectively, and observed for the same period, 31.8 ºC temperature. Comparing the data, the difference between the results can be attributed to the higher proportion of fish waste in relation to the wood shavings (7: 3) and also to the high moisture content present in these substrates, which was 79.9% and 62.0 %, respectively. These factors together with the addition of 5.5 L water per layer may have temporarily inhibited the microbial activity in the medium, which is responsible for the increase in internal temperature of the biomass and stabilization of the organic matter.

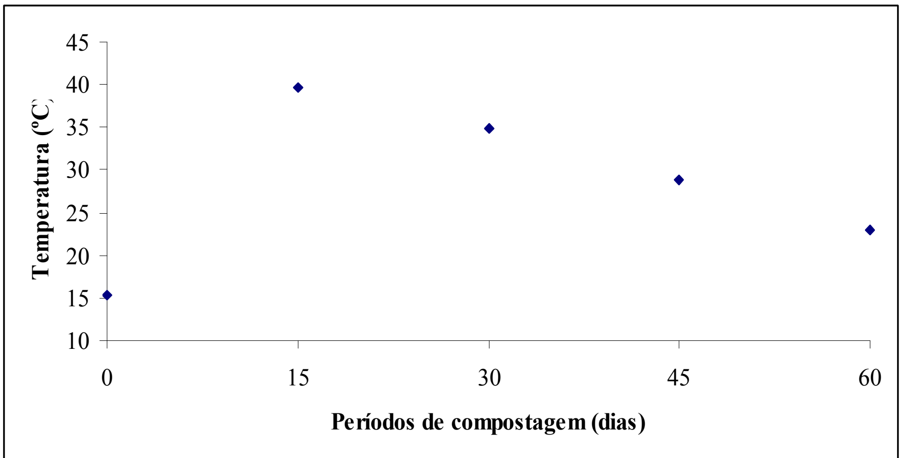

Figure 1. Mean values of biomass temperature during the composting process of the mixture of fish waste (skin and fin) and reused wood shavings at the 7: 3 mass ratio

The moisture content directly affects the transport of dissolved nutrients, which are required by the metabolic and physiological activities of the microorganisms (LI et al, 2013). Nikaeen et al. (2015) argue that the optimal moisture content of the substrate mixture should be between 55 and 64 %, in order to stimulate a higher microbial activity in the medium. However, Kumar et al. (2010) emphasize that the optimal moisture content is closely related to the type of composted residues. Devine et al. (2014) point out that the water balance is affected by the characteristics of the material, such as moisture content, chemical composition and physical structure. Kunz et al. (2008) evaluated different substrates for composting pig slurry and verified that sawdust had a greater efficiency in evaporating water than the shavings. The authors attributed this result to the smaller particle size of the substrate, which reduced the heat loss to the external environment, increased the temperatures reached by the compost mass and resulted in a greater loss of moisture.

On the other hand, from day zero, there was an increase in temperature reaching 39.6 ºC at 15 days of composting, demonstrating the growth and development of mesophilic microorganisms in the biomass. Bacteria, fungi, and mesophilic actinomycetes, which are dominant in the first three days of composting, feed on readily available organic matter components such as sugars, amino acids, proteins and nucleic acids, rapidly causing temperature rise due to the release of heat by part of the microbial metabolism (VERGNOUX et al., 2009). However, the persistence of these microorganisms in the period suggests that the colonization of the biomass by the thermophilic microbiota may have been impaired by the moisture content (62.8%) of the substrate mixture. The excess water causes a displacement of air, present in the porous spaces of the matrix, reducing the continuity between the pores, thus limiting the diffusion of oxygen (CHANG & CHEN, 2010).

In the subsequent periods, 30, 45 and 60 days, the biomass temperature decreased progressively, assuming the values of 34.8, 28.9 and 23 ºC, respectively. In the same way, the tests showed that the high moisture content of the composted waste mixture impaired the development of the process, which was aggravated by the absence of turning during the periods, which is suppressed in the composting process in cells. Nikaeen et al. (2015) emphasize that the moisture reduction rate of the environment is influenced by the aeration method.

This fact is more evident in Figure 2, where it can be observed the production of slurry from the 10 days of composting. The excess initial moisture of the substrates and biomass favors the fermentative metabolism, resulting in an incomplete decomposition of metabolites as well as organic acids (LIU et al., 2011).

Considering the total organic matter and organic carbon contents, there were significant reductions between the day 15 (77.6 %, 43.1 %) and the last two periods, 45 (70.5 %, 39.1 %), and 60 days (69.8 %, 38.8 %) of composting ($p < 0.05$). As expected, ash content increased significantly between the same periods ($p < 0.05$) (Table 2), showing a higher concentration of mineral components, resulting from the mineralization of the total organic matter by a heterogeneous microbial population present during the process (VALENTE et al., 2016a). The results disagree with Orrico Junior et al. (2012), who state that the increase in mineral content is an indication that the process was conducted in an appropriate manner, avoiding excess moisture, slurry formation and nutrient leaching.

As previously emphasized, excess moisture from the composted substrate mixture resulted in increased production and release of slurry and possibly nutrient losses through the leaching process (Figure 2).

Figure 2. Production of slurry from 10 days of composting the mixture of fish waste and reused wood shavings at the 7: 3 mass ratio

Table 2. Chemical composition of the mixture made of fish waste and reused wood shavings at the 7: 3 mass ratio, subjected to different composting periods

Chemical composition	Composting periods (days)				IN-25*
	15	30	45	60	
pH	9.2	9.4	9.3	9.3	≥ 6.0
Moisture (%)	62.8^{A}	57.5^{AB}	56.3^{AB}	44.7^{B}	≤ 50%
Organic matter (%)	77.6^{A}	73.9^{AB}	70.5^{B}	69.8^{B}	≥ 40%
Ash (%)	22.4^{B}	26.1^{AB}	29.5^{A}	30.2^{A}	-
Total organic matter (%)	43.1^{A}	41.0^{AB}	39.1^{B}	38.8^{B}	≥ 15%
Total nitrogen (%)	4.3	3.5	4.0	3.4	≥ 0.5%
Carbon/nitrogen ratio	10.4	12.4	10.3	11.6	≤ 20
Compost mineralization index	0.5^{B}	0.6^{AB}	0.8^{A}	0.8^{A}	-

Means followed by different uppercase letters, in the same row, are significantly different by Tukey's test at 5%. *Normative Instruction 25/2009 (BRASIL, 2009).

The significant increase in the mineralization index of the compost in the last two final periods of the process, 45 (0.8) and 60 days (0.8) ($p<0.05$), shows a higher mineralization of the total organic matter, which is directly related to the increase in CO_2 release by respiratory activity of microorganisms. Nevertheless, the results obtained were lower than those recommended by Drozd et al. (1997), who state that the higher the index (> 1.30), the greater the mineralization of the total organic matter. Valente et al. (2014b) studied the composting of dog corpses and also found a lower mineralization of the compost and attributed it to the type of carbon present in the wood shavings and the high initial C/N ratio (191/1). In a more recent study, Valente et al. (2016b) found mineralization indices ranging from 0.1 to 0.2 at the end of composting a mixture of marine fish waste and rice husk and also related it to the high C/N ratio (74.7 /1) of the structuring agent.

Although no significant difference was detected in the total nitrogen content between the periods (P> 0.05), there was an increase at 45 days (4.0 %) when compared to the 30 (3.5 %) and 60 days (3.4 %), due to the death of part of mesophilic microorganisms, which incorporate and immobilize the nitrogen in their cellular protoplasm (CAYUELA et al., 2009), which can be confirmed in Figure 1, where it is observed a biomass temperature reduction at 45 days (28.9 ºC) of composting. This fact was also mentioned by Valente et al. (2016b), who studied composting the mixture of marine fish waste and rice husk at 1: 3 and 3: 3 ratios.

As a result, there was a greater reduction in the C/N ratio at 45 days (10.3/1) of composting compared to the other periods. Differently, at 60 days, there was an increase in the C/N ratio (11.6/1) due to reduced microbial metabolic activity in the period. Both situations contributed to the reduction in biomass temperature in the last two periods of the composting process. The results showed that the low initial C/N ratio of fish waste (3.8 ± 0.09) and wood shavings (14.8 ± 0.07), reused for three consecutive times, affected the development and growth of thermophilic microorganisms during 60 days of composting. Kumar et al. (2010) studied the composting of grass residues and food leftovers, and found that the interaction between high moisture content (60 %) and low C/N ratio (19.6/1) affects the reduction of biodegradable organic matter, due to reductions in oxygen transport and microbial activity. Gao et al. (2010) analyzed the temperature behavior in composting the mixture of excreta of birds and sawdust at ratios of 16.3: 1, 6.9: 1 and 3.4: 1, with an initial C/N ratio of 12/1, 18/1 and 28/1, respectively. The authors verified that the thermophilic phase of the composting process of the mixture with initial C/N ratio of 12 and 18/1 was lower than that of the mixture with 28/1 C/N ratio, being attributed to the insufficient amount of carbon in the proportion of the substrates composted

Another aspect concerns the acidic pH of the initial substrates, fish waste (6.5 ± 0.07) and reused wood shavings (5.3 ± 0.09), which after 15 days of composting the mixture at the 7: 3 ratio, reached alkaline values, remaining until the end of the process. The increase in pH can be attributed to the production of ammonia associated with protein degradation, as well as the decomposition of organic acids (PANDEY et al., 2016).

Outro aspecto diz respeito ao pH ácido dos substratos iniciais, resíduos de pescado (6,5 ± 0,07) e maravalha reutilizada (5,3 ± 0,09), que após 15 dias de compostagem da sua mistura na proporção 7:3, atingiram valores alcalinos, mantendo-se até o final do processo. O aumento do pH pode ser atribuído á produção de amônia associada á degradação da proteína, bem como a decomposição dos ácidos orgânicos (PANDEY et al., 2016).

The values found for the chemical composition of the compost produced at the end of the 60 days of composting are within the range recommended by IN-25/2009 (BRASIL, 2009). However, the low C/N ratio (11.6/1) of the compost could reduce the vegetative development causing chlorosis of leaves (MALAVOLTA et al., 2002), due to the loss of N by volatilization during the decay of organic matter in the soil (KIEHL, 1985). Valente et al. (2013) emphasize that, in addition to the C/N ratio, other parameters for assessing the quality of organic fertilizer should be taken into account by IN-25/2009 (BRASIL, 2009), so that the product is considered humified and/or mature.

The present study shows that the composting process is an efficient alternative for the valuation of fish waste. The compost produced complies with Normative Instruction 25/2009 of the Ministry of Agriculture, Livestock and Supply, to be marketed as organic fertilizer. Nevertheless, the C/N ratio less than 15/1 associated with the high moisture of the substrate mixture inhibits the biomass temperature increase. Wood shavings reused for three consecutive times serves as a source of nitrogen. The addition of water to the composting process should be suppressed when using 7 kg fish waste and 3 kg reused wood shavings.

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Data de recebimento: 06/07/2017
Data de aprovação: 24/10/2017