Physicochemical Characterization of a Feed Based on Food Waste for Broilers and Organic Chickens

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ABSTRACT

The city of Oujda has a very significant production of solid waste that annually exceeds 340,000 tons, of which the organic fraction represents at least 70%. In order to promote the recovery of solid organic waste, a study was carried out on an alternative food made from food waste (FW) in the city of Oujda (Morocco). Before being applied on different flocks of chickens (industrial broilers and farmer broilers), this Lab-Prepared Feed was analysed to determine its organo-mineral composition in comparison to other composed poultry feeds that are marketed in Morocco. The results of organo-mineral characterization showed a composition of 13% in total nitrogen, 7% in mineral matter and 4% in fat, while for the composed poultry feeds, these components were 15%, 6% and 5%, respectively. The composition of nutriment found for the studied materials may promote the food waste recovery to be used as a raw material of the Lab-Prepared Feed (LPF). Thus, it may enable to replace, under sustainable view, the composed poultry feeds, which have presently become very expensive due to various economic factors.

Keywords: pollution, food waste, poultry feed, physicochemical characterization, nutrient quality, Morocco.

INTRODUCTION

At present, even if its management has been improving for several years, the quantity of municipal solid waste (MSW) produced continues to increase, under the effect of economic growth and urbanization (Millati et al., 2019) as well as nationally (Croitoru et al., 2017). According to the report published in 2018 by the World Bank, the rate of municipal solid waste generation internationally is 2.01 billion tons per year, of which at least 33% is not carefully managed and respectful to the environment (Kaza et al., 2018). Moreover, a significant increase in the waste production rate per each capita has also been predicted as 1.2 kg to 1.42 kg a day until 2025 (World Bank, 2012; Scarlat et al., 2015).

In Morocco, declared by the World Bank (2017) and the Moroccan Ministry of the Environment (MdE) (2016), only 10% of household solid waste was recycled in 2017 and national production increased from 6.3 to 7.4 million tons per year between 2007 and 2015, i.e. an increase rate of 17.5% (Croitoru et al., 2017). Thus, according to PNDM, 5.5 MT is generated in an urban environment which is the equivalent of a ratio of 0.76 kg/inhabitant/day with a predominance of organic matter (OM), which represents up to 70% of the total weight and is characterized by high humidity (65%) (Hasnaoui et al., 2017), whereas in the city of Oujda, this OM fraction exceeds 73% with a humidity of 69.8%, as reported by Arabi et al. (2020). Indeed, solid waste management is one of the most complex and costly public services,

even when they are well organized and functioning properly (Scarlat et al., 2015). Moreover, the current structure of waste management alters the quality of life and health of the populations as well as the economic and social development of the country. Certainly, given that production will considerably exceed the population growth of more than double by 2050, according to the World Bank (Kaza et al., 2018), environmental problems concern each individual in the world.

Generally, the collection and treatment of waste is done by municipal authorities, as well as by private companies using certain technologies which depend on several considerations, such as economic factors, technology and local situations (Millati et al., 2019). However, the International Solid Waste Association (ISWA) reports that globally, landfilling remains the primary method of solid waste disposal. In particular, low- and middle-income countries still depend almost exclusively on the landfill or dumping of waste (World Bank, 2012).

However, depending on improvements in waste management practices, economic development, and improved income, waste collection rates may increase in the future (Scarlat et al., 2015). As a result, the quantities of waste generated and collected for 2012 and expected for 2025 in the urban areas in Morocco were estimated; they are 10.326 103 T/year and 16.384 103 T/year against 8880 103 T/year and 14.745 103 T/year of collection, respectively. This shows the magnitude of the difference between the waste generated and the quantities actually collected, which can cause a sharp increase in the quantity of the waste produced until 2025 and which will probably not be collected (Scarlat et al., 2015).

Moreover, since the introduction of the National Household Waste Program in 2008, Morocco has markedly improved the rate of deposit in controlled landfill of MSW collected, from 10% before 2008 to 44% in 2015 (Croitoru et al., 2017; CCOT, 2020). Indeed, the characterization of household and similar waste is a key element in achieving the strategic objectives of the PNDM, namely the recovery of 20% of DMA by 2020 (Elkadi et al., 2016). Hence, the importance of carrying out a characterization of production in this area for adequate management and finding the best method to develop it for various purposes (Das et al., 2019). These wastes are generally classified as organic and inorganic matter (paper, plastic, glass, metals, etc.).

Admittedly, the organic fraction, which represents between 60% and 80% of the total waste production at the national level (Naimi et al., 2016), includes food waste. The latter, which are produced by the processing, cooking, distribution, production and consumption of food (Abdel-Shafy et al., 2018), are largely generated in many sectors (households, hotels, supermarkets, restaurants...) has increased with the development of economic and population growth at the national level (El Gnaoui et al., 2020).

Moreover, to avoid the various threats caused by these wastes, the authors aimed to use a Lab-Prepared Feed (LPF) based on kitchen food waste, instead of being landfilled, or abandoned in nature or in waterways, for an application in the poultry sector (such as substitute food). Thus, this experience will be considered as a new incentive for a rewarding management of this material.

The objective of this study was to compare, from a nutritional value point of view, a poultry feed prepared in the laboratory (based on kitchen waste) with two other compound feeds marketed as poultry feed, through a series of physicochemical analyses after their stabilization and granulation.

MATERIALS AND METHODS

Preparation of Lab-Prepared Feed (LPF) samples

The FW collected mainly contains kitchen waste, including fruit, vegetables and cooked food. Thus, sampling was carried out from five collection points (restaurants that were randomly chosen in the city of Oujda).

After collection, the waste samples were mixed and stored on wet wastes (ADEME, 1993); the authors opted for a manual separation for the characterization of waste according to the main categories and sub-categories (fermentable, paper, glass, plastics, etc.) (Elkadi et al., 2016), but, only the food fraction was of interest.

The drying of this sorted food fraction was done following two methods:
- Sun drying: food waste is left in the sun at an average temperature of 35°C on a surface so that the Sun penetrates very quickly, thereby speeding up the drying process.
- Oven drying: the samples are placed in an oven, a series of drying was carried out at

different temperatures: 50°C, 55°C, 60°C, 70°C, 80°C, 90°C and 100°C. This is in order to choose the ideal temperatures for good drying and to save time.

After obtaining dry FW, the authors managed to characterize them through a series of physicochemical analyses.

Physicochemical characterization of Lab-Prepared Feed (LPF)

The pH was measured with a pH meter (WTW ph340) and the humidity is a characteristic which is determined by drying at the temperature of 105°C, to a constant weight, the time is usually 24 hours (Francois, 2004; Aloueimine et al., 2005). The humidity level is the loss in mass compared to the initial mass:

$$H = (P0 - P1) \cdot 100/P0 \qquad (1)$$

where: H (%) - percentage of humidity; $P0$ (kg) - initial weight; $P1$ (kg) - final weight after drying.

The dry matter content (DM) was determined by desiccation, according to the standardized methods used in soil analysis according to the NF ISO 11456 standard, (1994) (Francois, 2004), in an oven at 105°C until a constant weight is obtained, then cooled and reweighed. Following the analysis of DM, the determination of the volatile dry matter (VDM) rate, which is the most commonly used method to evaluate organic matter (Elkadi et al., 2016), was carried out according to the AFNOR NF standard. U44160, (1985). The previously dried samples were calcined in a muffle furnace at 550°C for 4 hours, the loss in mass, related to the quantity of dry matter, corresponds to the level of volatile dry matter (VDM) (Maxime, 2008; Cachet, 2005; Lacour, 2012). The organic matter content is obtained by weighing difference between the mass of the dry waste (M1) and the mass of the calcined waste (M2) (Elkadi et al., 2016).

$$Mo \% = (M1-M2) \cdot 100/M1 \qquad (2)$$

While the mineral matter (MM) of the samples was determined by weighing the residue after evaporation of water and removal of organic constituents by calcination at 550°C (Achour, 2008).

The protein assay was done by the Kjeldahl method after mineralization with pure sulfuric acid and in the presence of a catalyst (K_2SO_4 and $CuSO_4$), the nitrogen compounds were mineralized in ammonium sulfate. The ammonia displaced by the soda was engrained by steam and dosed by sulfuric acid. This method gives the percentage of Total Nitrogenous Matter (TNM) (N%) of the samples (Cachet, 2005).

The protein percentage % Pt is determined by the relation (Abdollahi et al., 2015; Gudiso et al., 2018):

$$\% Pt = \% N \times 6.25 \qquad (3)$$

The determination of the wall constituents (NDF, ADF and ADL) was made according to the method of Van Soet (1982). It is based on the splitting of the cell into cell content and the wall. Each part is solubilized by a specific process, constitutes the insoluble part (cellulose, hemicellulose and lignin) (Maxime, 2008; Cachet, 2005; Komilis et al., 2003; Tchobanoglous et al., 1993; Van Soest et al., 1991). This method developed for the analysis of the nutritional value of fodder intended for animal feed, the protocol can be implemented on compost, waste or categories of waste (Binner et al., 1997). The separation was realized according the methods indicated by INRA (2016):
- NDF (cellulose, hemicellulose and lignin): neutral detergent method.
- ADF (cellulose and lignin) and ADL (lignin): acid detergent method.

The determination of minerals (Ca, Mg, Fe and P) was carried out by atomic absorption spectrophotometer according to the method AOAC (1990) (INRA, 2016; Alinorm, 1995).

The fat content (FC) was determined through the extraction with the Soxhlet method using ether as a solvent (Cachet, 2005; Almendros et al., 2000). The crude fiber (CF) content is determined by using the Weende method using a crude fiber extractor. It constitutes the insoluble residue after treatment with an acid and then with a base (Cachet, 2005; Djakovitch, 1988).

RESULTS AND DISCUSSIONS

Quality monitoring

Organic/mineral analyses and others

The average OM composition is around 93% DM for commercial foods and those prepared in the laboratory (Figure 1), which complies with the
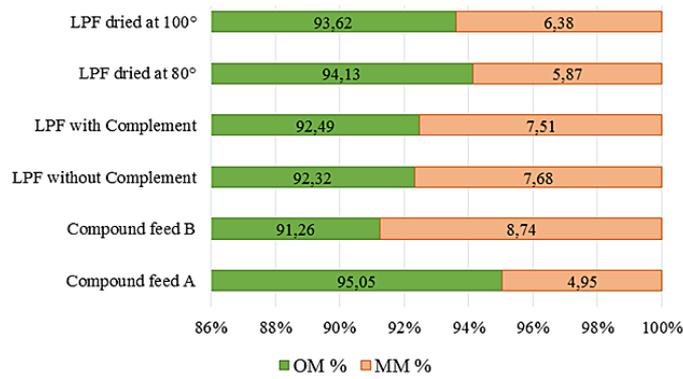
Figure 1. Organic Matter (OM) and mineral matter (MM) content of commercial foods (A, B) and new Lab-Prepared Feed

recommendations in force (92 %) (Papadomichelakis et al., 2019), indicating that food waste contains high levels of OM (El Gnaoui et al., 2020).

While the average rate of mineral matter (MM) is about 6% DM and the same value (6.1%) declared by Seven et al. (2012) together with 980 g/kg (98%) revealed as the maximum content in MM (Fortuoso et al., 2019). The samples of different foods have a dry matter content (DM) of approximately 89% MB (Figure 2).

These relatively high rates are in part due to the pre-treatment by drying, sorting and reducing the size of kitchen scraps before drying (Nikiema et al., 2015), the same observation was made by (Lacour, 2012). This value is almost the same as that defined for the diet of broilers (92%) (Wang et al., 2015) and 90.8% (Papadomichelakis et al., 2019). In turn, the average moisture content is around 10% DM which is similar to the minimum result (20 g/kg) (Fortuoso et al., 2019).
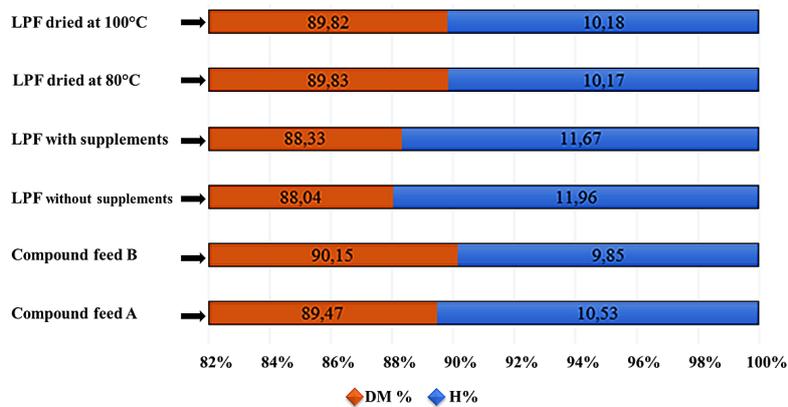

Figure 2. Dry matter content (DM) and humidity (H) of commercial foods (A, B) and new Lab-Prepared Feed
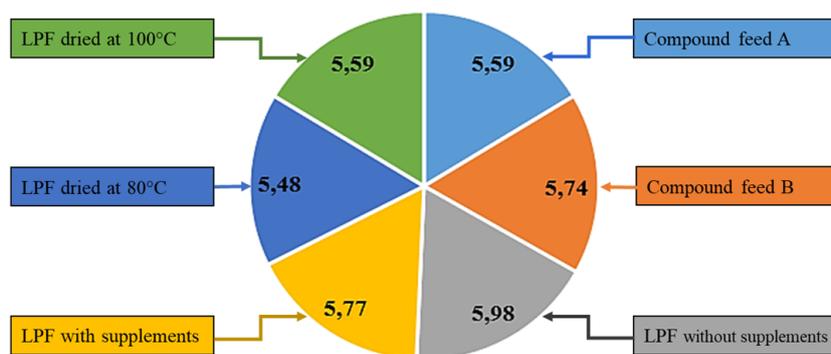

Figure 3. The pH of commercial foods (A, B) and new Lab-Prepared Feeds

The pH average value of the four food waste samples is around 5.5 (Figure 3), which is the same value found for both compound foods. Indeed, the sale pH value is cited by in the studies reporting that organic solid waste has a pH between 5 and 9 (Nikiema et al., 2015, Charnay, 2005).

This pH value can be explained by the onset of acidification linked to the presence of certain waste of an acidic nature (lemon peel, orange peel) (Nikiema et al., 2015).The food waste has a lower pH than the results obtained for the six foods, and it amounts to 4.7 (El Gnaoui et al., 2020).

ADF, NDF and ADL fiber contents

The fiber content in foods is an important component to know, it is the most difficult part of the food to digest (Mertens, 1997). These levels generally refer to the constituents of cell walls, mainly the hemicellulose, cellulose and lignin fractions. The results of the chemical analysis of the different food samples presented in (Table 1), reveal that the oven-dried foods and the compound feed B are rich in NDF with 58.23% and 50.35% contents of MS for 80°C and 100°C, respectively. In turn, the sun-dried food without / with compliment and the compound food A have respective contents of 30%, 36% and 36.54%. For the ADL content, the highest is that of LPF with Complement which consists of 28.52%, while other foods have low levels. On the other hand, the comparison between the ADF values for the new foods prepared in the laboratory and the commercial foods did not reveal any difference because their levels are around 10%.

These results are explained by the composition of the organic Matter of MSW, which includes three main categories among which are natural organic polymers, or biopolymers, grouping starches, cellulose, hemicelluloses and lignin which could be broken down (Gourdon, 2002). Indeed, the results obtained are similar to those found in Moringa forage flour, made from leaves and stems, used in the study by Valdivié-Navarro et al. (2019) who found that this flour has a high content of these types of fibers (33.31 to 66.34% NDF and 5.43 to 13.66% ADL). In turn, the ADF content is lower compared to that of Moringa's forage flour which contains 22.23 to 45.91% ADF. However, these high levels must result in a low metabolizable energy (ME) content for poultry (Valdivié-Navarro et al., 2019). In addition, 686 g/kg of NDF and 403 g/kg of ADF are revealed in palm kernel meal intended for poultry feed (Abdollahi et al., 2015).

Chemical contents

The set of chemical analyses on the different food samples (commercial and novel food prepared in the laboratory) led to the results shown in (Table 2). The chemical analyses show that the samples have an average content of 15.7% TNM for the compound feed and 13.03% TNM for the NLF. However, these results are lower than the standards (21% TNM) declared for organic chickens (Lehmann, 2003). Moreover, the content of palm kernel meal used as a staple diet for broilers is 25.4 g/kg in total nitrogenous matter (TNM) (Abdollahi et al., 2015).

Table 1. Fiber content in (% DM) of commercial foods (A, B) and new Lab-Prepared Feeds

Samples	Compound feed A	Compound feed B	LPF without Complement	LPF with Complement	Food dried at 80°	Food dried at 100°
NDF %	36.54	48.5	30.01	36.03	58.23	50.35
ADF %	8.83	13.7	9.12	9.86	7.39	10.1
ADL %	2.64	11.91	3.51	28.52	5.43	4.43

ADF: acid detergent fiber; ADL: acid detergent lignin; NDF: Neutral detergent fiber.

Table 2. Chemical composition of commercial foods (A, B) and new Lab-Prepared Feeds

Samples	Compound feed A	Compound feed B	LPF without Complement	LPF with Complement	LPF dried at 80°	LPF dried at 100°
TNM %	14.32	17.26	12.2	12.23	14.42	13.27
CP (g/kg)	895	1078.75	762.5	764.37	901.25	829.37
CF %	3.49	8.87	3.83	7.03	3.59	7.54
GM %	5.61	5.81	3.88	3.18	6.2	5.1

TNM: total nitrogenous matter; CP: crude protein; CF: crude fiber; FC: fat content.

As a result, the crude protein content is high for the different types of samples analyzed and exceeds the standards 21%, 19% and 16% CP for organic broilers (Roinsard, 2015), as well as 21–22%, 19–20% and 17–19% CP for broilers during the three phases of rearing (start-up, growth and finish) (Vantress, 2015). Similarly, the results obtained are superior to those reported by several authors who used the diets for rearing broilers containing 198–226 g/kg (Seven et al., 2012), 18.42%, 17.95% and 18.05% of CP (Liu et al., 2018) and 214.3 g/kg, 196.7 g/kg and 187.0 g/kg (Saadatmand et al., 2019) for the start-up, growth and finish phases, respectively. Moreover, Laudadio et Tufarelli (2010) declared CP contents of 20.56% and 20.49%, compared to the values of 21% and 19% declared by Kalantar et al. (2019), during the two start-up and finishing phases in poultry farming.

Regarding fat content (FC), according to the table, the contents are between 3% and 6% for the different samples and which belong to the margin of the food requirement in fat declared by the Technical Institute of Organic Agriculture (ITAB) (Roinsard, 2015) (between 2% and 7%) and 6% fat (Lehmann, 2003) to produce broilers in organic farming. Indeed, broilers need the same fat content of 5.35% (Tufarelli et al., 2015; Fu et al., 2019), also Laudadio et Tufarelli (2010) used two diets containing 3.93% and 3.54% fat for broiler rearing. Moreover, these FC levels can be explained by the composition of the organic matter of food waste rich in proteins and lipids (Gourdon, 2002).

For crude fiber (CF), the highest levels are 8.87%, 7.54% and 7.03% for compound feed B, Lab-Prepared Feed dried at 100 °C and dried in the sun with compliment, respectively. These levels are higher than the 5% CF standard for organic chickens (Lehmann, 2003), while the other three samples have a lower composition which is

around 3% CF. However, broilers have a low requirement for this matter, Liu et al. (2018) used a diet based on fermented broccoli waste (7.4 g CF/100g) in breeding, and the content is between 2.55% and 2.89% CF. In addition, the 2.8% CF content is declared (Tufarelli et al., 2015; Fu et al., 2019). On the other hand, the results obtained are lower than those found in the Moringa fodder flour used in the study carried out by Valdivié-Navarro et al. (2019) who found that this flour has a high crude fiber content of 14.50–44.32%.

Nutritional composition

Regarding the nutritional value, the contents of the different samples in nutritional elements are mentioned in (Table 3). the three samples (the food without compliment, the food compounds A and B contain a potassium levels (K^+) that do not exceed 10%. Whereas the LPF with compliment as well as the LPF dried at 80°C and 100°C consist of 15.5%; 18.2% and 21.7% of K^+, respectively.

These results respect the standards 0.60–0.95%, 0.60–0.85% and 0.60–0.80% K + as minimum levels for the rearing of broilers during the start-up and growth phases and finishing (Vantress, 2015). Moreover, the content of the basic feed for broilers is 6.4 g/kg K^+ (0.64%) (Abdollahi et al., 2015). However, these values are lower than the standard declared by Ognik et al. (2017) which is between about 31% and 40% for poultry farming.

Concerning the phosphorus content, the results found for compound feeds A and B (1% of TP) are better compared to the new laboratory food (0.6% and 0.7%). These levels obtained are higher than those declared by Vantress, (2015) which are at least 0.45%, 0.42% up to 0.38% TP during the three phases of broiler rearing, whereas they are similar to those revealed by Fu et al. (2019), amounting to 0.73% and also

Table 3. Mineral composition of commercial foods (A, B) and new Lab-Prepared Feeds

Samples	Compound feed A	Compound feed B	LPF without Complement	LPF with Complement	LPF dried at 80°	LPF dried at 100°
K^+ (%)	4.6	6.5	9.9	15.5	18.2	21.7
TP (%)	1	1.2	0.6	0.7	0.7	0.6
Cu (mg/kg)	0.04	0.1	0.04	0.04	0.06	0.07
Fe (mg/kg)	1.43	1.96	2.82	3.8	1.27	1.77
Mn (mg/kg)	0.19	0.93	0.16	0.23	0.11	0.13
Zn (mg/kg)	2.3	1.7	0.78	1.37	1.9	2

K^+: potassium; TP: Total phosphorus; Cu: copper; Fe: iron; Mn: magnesium; Zn: zinc.

0.66% Kwiecień et al. (2016). In turn, the phosphorus content ranges from 0.39%, 0.44% up to 0.48% (Abolfathi et al., 2019), 0.40 %, 0.35 % and 0.30% for the three phases of breeding (start-up, growth and finish), respectively, (Fortuoso et al., 2019) as well as 0.56% (Yang et al., 2018). However, the food requirement for TP is between 0.42% for the start-up phase and 0.35% for growth and finishing in organic broiler farming (Roinsard, 2015), thus, (Lehmann, 2003) specified 0.75% as the content of phosphorus.

On the other hand, the content of trace elements in different samples is very low. In fact, the Zn, Cu, Mn and Fe show, the values ranging between 0 and 3 mg/kg, 0 and 1 mg/kg, 0 and 3 mg/kg, 1 and 3 mg/kg, respectively. Therefore, these samples contain less concentration in these elements, compared to the specified standards for organic chicken farming, which are 9 mg/kg in Cu, and 80 mg/kg in Zn (Lehmann, 2003). Nevertheless, the standards' content specified for broilers according to Akhavan-Salamat et al., (2019), vary between 30 and 33 mg/kg in Zn, 7 and 9 mg/kg in Cu, 17 and 20 mg/kg in Mn. According to Kwiecień et al. (2016), these concentrations are mainly determined as 40 mg/kg in Fe, 16 mg/kg in Cu, and 100 mg/kg in Mn. In addition, the content of trace elements for the diet of broilers are 103.5 mg/kg Zn, 127.2 mg/kg Mn and 7.5 mg/kg Cu (Fu et al., 2019). However, Djakovitch (1988) indicated these minimal values as 40 mg/kg in Fe, 20 mg/kg in Mn, 20 mg/kg in Cu and 100 mg/kg in Zn. Instead, Abolfathi et al. (2019) specified that the minimal levels of diet were 110 mg/kg, 60 mg/kg, 90 mg/kg, and 10 mg/kg in Mn, Fe, Zn, and Cu, respectively. While, Fortuoso et al. (2019) reported that these minimal values were 80 g/kg, 50 g/kg, 70 g/kg, and 10 g/kg, in term of Mn, Fe, Zn, and Cu, respectively.

CONCLUSIONS

From the analysis of the present study results, it can be concluded that sun drying food waste does not represent many advantages in terms of drying time and nutritional composition compared to commercial food and that oven-dried. Regarding the oven drying process at 80°C and 100°C, besides being fast and very handy, it seems to have a good yield and better physicochemical quality of food yields, by preserving most of the nutrient compounds. In fact,

the eating behavior and attitude, which change with the time of year, are important factors contributing to the heterogeneity of leftover meals, which necessitates in general, batch production, with analyses for possible improvement if necessary, so the manufacturing process seems well-developed and deserves to be tried on an industrial scale. Admittedly, the valorization of these leftovers from restaurant kitchens in the City of Oujda is very feasible in terms of the production of substitute feeds intended for the poultry sector.

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