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Effect of Autoclave, Microwave Radiation and Their Combination on the Metabolic Energy and Nutrient Digestibility of Wheat Screening Waste in Broilers

Short Communication

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ABSTRACT

This study investigated the effect of autoclaving and microwave radiation on the chemical composition, metabolic energy, and nutrient digestibility of wheat screening waste. Autoclave treatment involved heating the waste at 120 °C for 45 minutes, while microwave treatment utilized 1000 watts for 5 minutes. The experimental treatments included untreated waste, autoclaved waste, microwaved waste, and autoclaved followed by microwaved waste. Both heat treatments resulted in a decrease in gross energy, with the microwave treatment exhibiting the most significant effect. Additionally, the microwave treatment and the sequential autoclave followed by microwave treatment led to a slight reduction in dry matter content. Autoclaving improved the metabolisable energy of the waste by 23.4%, while the combined autoclave and microwave treatment improved it by 9.7%. However, microwave processing alone reduced the metabolisable energy by 25.4%. The heat treatments also resulted in notable changes in the waste's chemical composition, including decreased crude protein, gross energy, and sugar content, as well as increased dry matter, crude fiber, acid-insoluble ash, calcium, and phosphorus.

KEY WORDS autoclave, broiler, digestibility, metabolisable energy, microwave, wheat screening waste.

INTRODUCTION

Wheat is a vital source of energy in animal nutrition. Previous studies have shown that wheat grain can be efficiently utilized, even without the inclusion of NSPase or phytase enzymes, when diets are formulated based on digestible essential amino acids (Mohammadi Ghasem Abadi *et al.* 2014). Wheat screening waste, which accounts for 8% to 12% of production, is a by-product obtained during wheat processing in flour, pasta, and seed breeding factories (Golian and Parsai, 1996). Various methods have been proposed to enhance the nutritional value of wheat and its by-products for chickens, including the supplementation of wheat-based diets with pentosanase for improved utilization of wheat non-starch polysaccharide (NSP) (Crouch *et al.* 1997). Non-enzymatic processing methods such as heating, autoclaving, soaking, sprouting, and fermentation have also shown successful results (Al-Kaisey *et al.* 2002; Skrede *et al.* 2007). This research aimed to investigate and compare the effect of thermal processing and microwave radiation on the chemical composition, metabolisable energy, and nutrient digestibility of wastes from milling.

MATERIALS AND METHODS

Five kilograms of wheat screening waste samples underwent heat treatments using an autoclave (at 120 °C for 45 minutes) and microwave radiation (1000 watts for 5 minutes). The experimental treatments consisted of:

1. Control treatment (untreated wheat waste)
2. Autoclaved wheat waste
3. Microwaved wheat waste
4. Autoclaved and then microwaved wheat waste

The dry matter, crude protein, crude fat, crude fiber, calcium, phosphorus, sugar, starch, and ash of processed and unprocessed wastes were measured following standard methods of AOAC (2005). Crude energy was determined using a bomb calorimeter. Nitrogen-free extract was also estimated using the formula:

Nitrogen free extract (NFE)= 100 - (% CP+% CF+% EE+% ASH)

Where:
CP, CF, EE and ASH: crude protein, crude fiber, ether extract (crude fat), and crude ash, respectively.

The apparent metabolisable energy corrected for nitrogen (AMEn) was measured using the *in vivo* method, involving the use of chromium oxide as an indicator and sampling of ileum contents of 35-day-old broiler chickens.

First, the reference diet was prepared without experimental samples, and then the experimental samples were mixed in a 1:1 ratio with the reference diet along with 0.3% of chromium oxide. For this purpose, 25 male broiler chickens of the Ross commercial strain aged of 35 days, were used (five chickens for each treatment). The chickens were housed in five dedicated breeding cages. The reference diets for the growth period were formulated according to the feeding guide of the Ross 308 strain. All diets were provided in mash form, and the chickens had *ad libitum* access to the feed.

At the end of the 42-day experiment, the ileal contents were collected by the flushing method, starting from 10 cm distal to the Meckel's appendix up to the ileocecal valve. The collected samples were stored at -20 °C until chemical analysis. Prior to analysis, the ileal content samples were dried in an oven at 60 °C for 72 hours, then weighed and ground using a laboratory mill.

The apparent metabolizable energy (AME) and apparent metabolisable energy corrected for nitrogen (AMEn) of the diets were calculated using following equations:

AME= GE diet – [GE excreta/digesta × (Cr_2O_3 diet/Cr_2O_3 excreta/digesta)]
AMEn= AME – 8.73 × N Diet - (Cr_2O_3 diet/Cr_2O_3 excreta/digesta) × N excreta / digesta

Where:
GE diet: gross energy per gram of feed.
GE excreta/digesta: gross energy per gram of ileal contents.
Cr_2O_3 diet: chromium oxide concentration per gram of feed.
Cr_2O_3 excreta/digesta: chromium oxide concentration per gram of ileal contents.
N Diet: nitrogen concentration per gram of feed.
N excreta/digesta: nitrogen concentration per gram of ileal contents.

After determining the apparent metabolisable energy value for the complete diet, the combustible energy content and composition of the experimental sample were calculated by subtracting the metabolisable energy of the experimental diets containing wheat waste (as the test diet) from the total metabolisable energy of the reference diet, using the following equation:

AMEn of the experimental sample= AMEn of reference diet – [(AMEn reference diet–AMEn experimental diet) / replacement level]

RESULTS AND DISCUSSION

Table 1 presents a comparison of the metabolisable energy values obtained in this study with the values estimated based on the regression relationships proposed by NRC (1994) and Borges (2003). The results are presented as a case report, and no statistical test tests were conducted. Table 2 shows the chemical compositions of different types of tested wheat wastes.

In this experiment, all thermal processes, including autoclaving, microwaving, and the combined use of both processes, resulted in a reduction in gross energy, with microwave treatment having the greatest effect. Additionally, there was an approximately 1% reduction in dry matter for samples subjected to microwave or autoclave + microwave treatments. The AMEn values were also influenced by the thermal processing. While the AMEn for the unprocessed wheat screening waste sample, based on dry matter or as-fed, was 2401.71 and 2211.73 kcal/kg, respectively, the autoclave treatment increased it to 3552.56 and 3303.52 kcal/kg, respectively, indicating a 47.9% increase. The use of autoclave followed by microwave also resulted in a 32.8% increase in the metabolisable energy of wheat screening waste, while microwave processing alone led to a 20.37% decrease in AMEn.

Table 1 Comparison of the metabolizable energy values of different types of wheat waste obtained in the equilibrium experiment with the values estimated based on regression relationships

The type of wheat waste	DM	GE[1]	AMEn (kcal/kg)					
	%	in DM	in DM	As is	in DM	As is	in DM	As is
Without processing	92.1	4263.6	3063.9	2831.5	2774.9	2555.4	2401.7	2211.7
Autoclaved	93.0	4179.8	2118.3	2630.7	2578.6	2397.9	3552.6	3303.5
Microwaved	93.8	4087.0	3969.8	2786.6	2730.3	2552.5	1912.2	1794.3
Autoclaved and microwaved	93.2	4179.3	3025.6	2841.7	2685.4	2522.1	3190.7	2996.7
How to determine	Experiment		Estimating		Estimating		Equilibrium experiment	
Reference	Animal Science Research Institute		Borges *et al.* (2003)		NRC (1994)		Animal Science Research Institute	

[1] The gross energy (GE) of wheat bran residues in the standard tables with 17.88% of dry matter is 3875 kcal/kg and its AMEn is equal to 2783 kcal/kg (As is).
AMEn: apparent metabolisable energy corrected for nitrogen.

Table 2 Chemical compositions of different types of tested wheat wastes

The type of wheat screening waste	Chemical composition (%)											
	DM	CP	CF	AIA	CA	CF	Ca	P	TS	Starch	NFE	GE (kcal/kg)
Without processing	92.09	15.89	4.75	1.00	3.30	2.00	0.18	0.28	6.06	6.80	7.06	4263.60
Autoclaved	92.99	14.53	5.50	3.25	6.00	2.60	0.20	0.30	5.28	6.91	7.38	4179.76
Microwaved	93.83	14.30	4.75	3.30	6.30	2.60	0.20	0.30	4.87	7.02	7.95	4087.00
Autoclaved and then microwaved	93.92	14.31	5.25	2.40	5.30	1.60	0.25	0.29	4.62	7.52	7.54	4179.30

DM: dry matter; CP: crude protein; CF: crude fiber; AIA: acid-insoluble ash; CA: crude ash; Ca: calcium; P: phosphorus; TS: total sugar; NFE: nitrogen-free extract and GE: gross energy.

Table 3 Nutrient digestibility of basic rations, experimental rations and different types of waste tested (%)

Type of ration	DM	CP	CF	GE
Base (reference)	84.06	72.90	12.58	65.66
50% of basic ration + 50% of unprocessed wheat screening waste	82.24	63.88	13.04	61.34
50% of basic ration + 50% of autoclaved wheat screening waste	89.69	79.68	13.46	74.78
50% of basic ration + 50% of microwaved wheat screening waste	81.73	51.13	13.59	55.49
50% of basic ration + 50% of wheat screening waste, autoclaved then microwaved	87.91	76.92	11.61	71.34
Wheat screening waste without treatment	80.42	54.85	13.49	57.02
Autoclaved wheat screening waste	95.32	86.45	14.33	83.90
Microwaved wheat screening waste	79.41	29.36	14.60	45.33
Wheat screening waste autoclaved and then microwaved	91.77	80.94	10.64	77.02

DM: dry matter; CP: crude protein; CF: crude fiber and GE: gross energy.

Table 4 Metabolizable energy (ME) estimation of different types of wheat waste based on their raw energy digestibility

Type of wheat screening waste	GE (kcal/kg)	GE digestibility (%)	ME (kcal/kg)
Without processing	4263.60	57.02	2431.10
Autoclaved	4179.76	83.90	3506.81
Microwaved	4087.00	45.32	1852.22
Autoclaved and then microwaved	4179.30	77.02	3218.89

GE: gross energy.

Notable findings include a decrease in crude protein, crude energy and sugar content, as well as an increase in dry matter, crude fiber, acid insoluble ash, calcium and phosphorus in the thermally processed wheat screening waste samples.

Table 3 presents the nutrient digestibility of basic rations, experimental rations and different types of waste tested.

The digestibility experiment results indicated that replacing 50% of the control diet with processed wheat screening waste affected dry matter digestibility, with the diet containing 50% of autoclaved wheat waste showing approximately 3% higher dry matter digestibility.

The calculated values, after removing the effects of the control treatment, confirmed this difference, with a digestibility of 95.32% for the autoclaved samples, which was significantly higher than the untreated and microwave-treated samples.

In terms of crude protein, only the treatment with a higher digestibility compared to the control group, was the treatment contained 50% autoclaved wheat waste, which exhibited a digestibility of 68.79%. Notably, there was a significant decrease in the digestibility of crude protein in the treatment with 50% microwave-treated wheat waste, which reached only 13.51%.

These differences were also repeated in the calculated values, where the digestibility of crude protein in the autoclave and combined microwave-autoclave treatments were 45.86% and 36.29%, respectively. The calculated values for digestibility of crude fibers and energy, despite being approximate, also suggest the superiority of the autoclave treatment (Table 4).

The study conducted by Kianfar *et al.* (2013) demonstrated the positive impact of feeding autoclaved wheat on body weight (BW), weight gain (WG), and feed conversion rate (FCR) in quail. The improved performance of quails fed autoclaved wheat was attributed to enhanced nutrient digestibility and apparent metabolisable energy (AME). Afsharmanesh *et al.* (2008) also reported that heat treatment (80 °C for 15 hours) significantly improved FCR, AME, protein and phosphorus digestibility, while eliminating endogenous phytase and xylanase in wheat-based diets and increasing the soluble NSP levels. Grain steaming can alter the physical and chemical structure of grains, improve enzyme access to dietary components, and facilitate their utilization (Gracia *et al.* 2008).

Autoclaving (or high-pressure cooking) can generally have an impact on certain nutritional values of wheat grains (Mariscal *et al.* 2004; Perić *et al.* 2020):

1. Energy retrieval: autoclaving process reduces the binding or availability of certain nutrients, which typically increases the digestible and absorbable energy content for animals.
2. Fiber susceptibility reduction: autoclaving can break down the tough cell walls of wheat, making the fiber more digestible. This enhances the digestibility and thermal energy release through the breakdown of these ruptured cells.
3. Inactivation of antinutritional factors: autoclaving can destroy or reduce certain antinutritional factors present in wheat grains, such as antinutritional enzymes and antinutrient compounds. This improves the digestibility and absorption of nutrients, especially proteins, in the animal's digestive system.
4. Reduction of mineral imbalances: autoclaving processing leads to a reduction in nutrient imbalances, such as iron, zinc, and manganese, in wheat grains. This can improve the absorption of these nutrients by animals.

However, it's important to note that the impact of autoclaving on nutritional value can vary depending on the type of wheat grain and specific conditions. Generally, autoclaving can enhance nutrient digestion, absorption, and utilization from wheat grains by animals. Nonetheless, further empirical testing and scientific studies are necessary to fully understand the effects of autoclaving on the nutritional value of wheat grains and its by-products.

CONCLUSION

In conclusion, the utilization of autoclaving alone and autoclaving followed by microwave treatment in processing wheat screening waste resulted in a 23.4% and 9.7% increase in its metabolisable energy, respectively. However, microwave processing alone led to a 25.4% reduction in metabolisable energy. The significant findings included a decrease in crude protein, gross energy, and sugar content, as well as an increase in dry matter, crude fiber, acid-insoluble ash, calcium, and phosphorus in the heat-treated wheat screening waste compared to the untreated sample.

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