Evaluation of multi blade shear (MBS) for determining texture of raw and cooked broiler breast fillets with the woody breast myopathy

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ABSTRACT The objective of this study was to evaluate a novel multi-blade Shear (**MBS**) method for measuring texture properties of both raw and cooked broiler fillets (pectoralis major) with the woody breast (**WB**) myopathy. A total of 180 broiler breast fillets (60 normal [**NOR**], 60 moderate WB [**MOD**], and 60 severe WB [**SEV**]) in two meat states (fresh never-frozen, n = 144; frozen/thawed, n = 36) were chosen based on their WB scores. In each trial, half of the fillets were used for measuring raw meat texture and the other half for cooked meat texture measurement. Blunt Meullenet-Owens Razor Sear (**BMORS**) was used for comparison. In fresh raw broiler fillets, both the MBS and BMORS methods detected differences between NOR, MOD, and SEV fillets ($P < 0.001$). In cooked broiler fillets, the methods were equivalent in their ability to separate SEV from NOR fillets. The MBS measurements showed greater Spearman correlation coefficients with the WB scores ($r_s \geq 0.70$ in raw and ≥ 0.33 in cooked) compared to the BMORS measurements ($r_s = 0.63$ in raw and ≤ 0.27 in cooked) for both fresh and cooked breast fillets. In addition, the MBS measurements were either as precise as or more precise than BMORS measurements regardless of meat condition (fresh vs. cooked) and the shear parameter. These results suggest that the MBS method is more reliable in measuring tactile characteristics of broiler breast fillets with the WB myopathy compared with the BMORS method.

Key words: BMORS, chicken, pectoralis major, spearman correlation coefficient, wooden breast condition

INTRODUCTION

The woody breast myopathy (**WB**) is a recent chicken muscle abnormality (Sihvo et al., 2014; Owens, 2014; Petracci et al., 2015). The key difference between normal breast fillets (pectoralis major) and WB meat is tactile properties or hardness on the ventral side at the cranial end of raw broiler breast fillets (pectoralis major). Several instrumental methods have been used to characterize the tactile properties of raw WB samples (Chatterjee et al., 2016; Soglia et al., 2016; Sun et al., 2018; Pang et al., 2020). One of them is the

Meullenet-Owens Razor Shear (**MORS**) method. Chatterjee et al. (2016) reported that there were significant differences in both MORS force and energy between normal and WB meat. Bowker and Zhuang (2019) reported significantly greater values in both MORS and blunt MORS (**BMORS**) measurements of the WB fillets than the of normal breast fillets, regardless of raw meat state (fresh or frozen-thawed).

Among the existing instrumental methods for measuring meat tenderness, the razor shear method (MORS and BMORS) is one of the more recently introduced methods for assessing poultry meat texture. Several studies have shown good correlation between MORS measurements and tenderness in cooked broiler breast meat (Cavitt et al., 2004, 2005a,b; Xiong et al., 2006). The MORS method has some advantages over industry standards such as the Warner-Bratzler and Allo-Kramer (**AK**) shear methods. It needs almost no sample preparation and is less time-consuming, simpler to perform,

and equivalent in performance to the Warner-Bratzler and AK shear in predicting tenderness of cooked poultry breast meat (Cavitt et al., 2004 and 2005b; Xiong et al., 2006). A blunt version of the MORS (BMORS) was developed as an enhancement of the original method to improve discrimination among tough cuts of meat (Lee et al., 2008). In addition, BMORS circumvents the need to change shearing blades every 100 shears as required with the MORS method (Meullenet et al., 2004). Lee et al. (2008) showed on the same fillets that both the MORS and BMORS methods were equivalent in performance for predicting broiler breast meat tenderness, with a high correlation coefficient (0.99). However, the BMORS method was recommended for use as it has better discrimination ability on tough meat.

In both MORS and BMORS methods, the dimensions of the blade are typically 24-mm long, 8.9-mm wide, and 1-mm thick. Each shear made with the 8.9 mm blade is very limited in area on a broiler breast fillet. Shear values can vary significantly between locations within a chicken breast fillet (Smith et al., 1988; Papa and Lyon, 1989; Zhuang and Savage, 2009). Therefore, a minimum of four shears per fillet are recommended for a reliable estimate of tenderness using MORS, with five shears or more being required to further improve the reliability of the tenderness estimates (Lee et al., 2008). This recommendation makes the MORS/BMORS methods more time-consuming when large sample sizes (>100) are evaluated. In order to overcome this disadvantage, a novel multi-blade shear (MBS) apparatus was developed that has the ability to shear a larger proportion of the breast in a single pass. The ability of the MBS apparatus for measuring shear of both raw and cooked broiler breast fillets with different degrees of the WB myopathy in broiler breast fillets was investigated. Furthermore, the performance of the MBS to classify WB was compared to BMORS.

MATERIALS AND METHOD

Broiler Breast Fillet Samples

Individual broiler breast fillets (ca. 300) were collected from the deboning line of a commercial processing plant (ca. 3 h postmortem). The fillets were placed in plastic bags and transported in ice to the laboratory within 45 min. Fillets were trimmed to remove possible bone particles, excessive fat and connective tissues, and then categorized as normal (**NOR**), moderate WB (**MOD**), or severe WB (**SEV**) based on the incidence of hardened areas throughout the fillets and the severity of palpable hardness (Bowker and Zhuang, 2019). The samples were also scored as normal, moderate, or severe white striping based on previously established criteria (Kuttappan et al., 2012) on the prevalence and thickness of white striations on the surface of the muscle. Meat pH measurements were taken in the cranial end of the fillets using a Hanna Instruments 99163N portable pH/temperature meter with a spear tipped probe (Hanna Instruments, Woonsocket, RI). Raw color values (CIE L*a*b*) were measured on the dorsal surface (bone

side) of each fillet using a Minolta spectrophotometer CM-700d (Konica Minolta Inc., Ramsey, NJ) according to the method of Zhuang and Savage (2009). Over 2 separate days, a total of 180 fillets (60 NOR, 60 MOD, and 60 SEV) were selected based on their WB scores. Raw compression analysis was carried out on 15 randomly selected breast fillet samples (5 per category) using a cylinder probe of 12-mm diameter with a 490 N loading cell on a Texture analyzer (model TA-XT-Plus, Texture Technologies Corp., Hamilton, MA). Intact fillets were subjected to a single 30% compression strain exerted perpendicular to fiber orientation on the highest portion of the cranial side (Tasoniero et al., 2019). One half of the fillets (90 fillets in total and 30 per category; 24 for raw fresh and 6 for raw frozen/thawed) were used for raw texture assessment, while the other half (24 for cooked fresh and 6 for and cooked frozen/thawed per category) were used for cooked texture assessment.

Sample Preparation

Breast fillets were individually vacuum packed in bags (Seal-a-Meal bags, the Holmes Group, EI Paso, TX) after pH and color data were collected and either stored at 4°C overnight (for fresh samples) or in a -20°C freezer until use (for frozen samples). The frozen fillets were thawed at 4°C overnight before preparation for measurements. For raw samples, drip loss or purge loss was determined by the differences in weight before and after overnight storage at 4°C and thaw loss was determined by the weight differences before freezing and after thawing overnight at 4°C. For cooked samples, raw fillets were cooked in a Henny Penny MCS-6 combi oven (Henny Penny Corp., Eaton, OH) set at 83.9°C until samples reached a target endpoint temperature of 75°C. Before shearing, both raw and cooked fillets were cut to a uniform thickness of 2.5 cm using a plastic cutting block. Shear measurements of cooked fillets were conducted after fillets were cooled down to room temperature.

Instrumental Texture Analysis

Shear force of raw and cooked broiler breast was measured using a Texture Analyzer (Model TA-XT-plus, Texture Technologies Corp, Hamilton, MA) with a 490 N load cell. Razor blade penetration was perpendicular to the orientation of the muscle fibers with a penetration depth of 20 mm. The distance between BMORS and MBS shears and between two BMORS shears was at least one cm and the test speed of the blade was 10 mm/sec. The trigger force was set at 10 g. Fillets were sheared perpendicular to the fiber direction. Peak shear force (N) and total shear energy (N.mm) were recorded. BMORS force (**BMORS_F**) and BMORS energy (**BMORS_E**) was determined using a blunt MORS blade. MBS force (**MBS_F**) and MBS energy (**MBS_E**) were determined using the multi-blade apparatus (Jaccard

Figure 1. A multi-blade shear (MBS) probe. The multi-blade shear (MBS) probe has three rows of blades and eight blades for each row. The whole length of one row (eight blades) is 88 mm and the width between each row is 5 mm. The length and width of each blade are 4 mm and 1 mm, respectively, and the space between two blades is 8 mm.

Table 1. Characteristics of raw broiler breast fillets according to WB condition (LSmeans ± SE).

Traits	N[3]	WB[1] NOR	MOD	SEV
Fillet weight (g)	56	453.5 ± 20.3^{b}	570.6 ± 12.7^{a}	554.7 ± 12.4^{a}
Drip loss (%)	56	0.69 ± 0.19^{b}	1.34 ± 0.12^{a}	1.46 ± 0.12^{a}
Cook loss (%)	56	22.62 ± 0.99^{c}	26.97 ± 0.62^{b}	29.96 ± 0.61^{a}
Score of white striping[2]	56	1.22 ± 0.16^{c}	1.85 ± 0.10^{b}	2.38 ± 0.10^{a}
pH	56	6.00 ± 0.05	6.14 ± 0.03	6.11 ± 0.03
L*	56	60.52 ± 0.81	62.18 ± 0.51	60.70 ± 0.50
a*	56	-0.77 ± 0.27^{b}	-0.11 ± 0.17^{ab}	0.40 ± 0.17^{a}
b*	56	11.43 ± 0.53^{b}	13.82 ± 0.33^{a}	14.72 ± 0.33^{a}
Compression force (N)	15	19.30 ± 3.19^{b}	26.37 ± 6.49^{ab}	35.63 ± 9.56^{a}

[1]NOR = no woody breast; MOD = moderate woody breast; SEV = severe woody breast.
[2]White striping score (WS): 1 = no WS, 2 = moderate WS, and 3 = severe WS.
[3]Number of the fillets used for measurements.
[a,b,c]LSmeans values with no common superscript in the same row are different ($P < 0.05$).

Meat tenderizer, Jaccard Corporation New York, USA, Figure 1). The multi-blade shear (MBS) probe has three rows of blades and eight blades for each row. The length of each row with eight blades is 88 mm and the width between each row is 5mm. The length and width of each blade are 4 mm and 1 mm, respectively, and the space between each blade is 8 mm. Five BMORS and one MBS measurements were made on each fillet. The locations of the BMORS and MBS measurements were alternated as shown in Figure 2.

Statistical Analysis

Data for raw meat characteristics (Table 1) were analyzed by the General Linear Model procedure of SAS (version 9.2, SAS Institute Inc., Cary, NC, USA). The WB condition (NOR, MOD and SEV) was analyzed as the main effect and the Tukey's method was used to identify significant differences between means ($P < 0.05$). For the texture measurements, the mean of the five BMORS measurements from each fillet was used for the statistical analyses. The texture data were grouped based on cooking state (raw vs. cooked) and the data in each group were analyzed using a 2-way ANOVA (PROC GLM procedure of SAS) with a model that

included WB condition (NOR, MOD, and SEV), meat state (fresh never frozen vs. frozen/thawed), as well as their two-way interaction (WB × meat state) as main effects. The Tukey's method was used to identify significant differences between means ($\alpha = 0.05$). The relationships between shear values and WB scores were analyzed by calculating Spearman correlation coefficients (r_s) using the PROC CORR procedure of SAS. The relationships between shear measurements were analyzed by calculating Pearson correlation coefficients (r). For the purposes of discussion in this paper, the following descriptors were used to describe the relative strength of the correlations: weak (r = 0.20 to 0.39), moderate (r = 0.40 to 0.59), strong (r = 0.60 to 0.79), and very strong (r = 0.80 to 0.99) (Ith, 2014). Coefficients of variation (**CV** = standard deviation/mean) were calculated to compare the precision/repeatability of measurements.

RESULTS AND DISCUSSION
Characteristics of Raw Fillet Samples

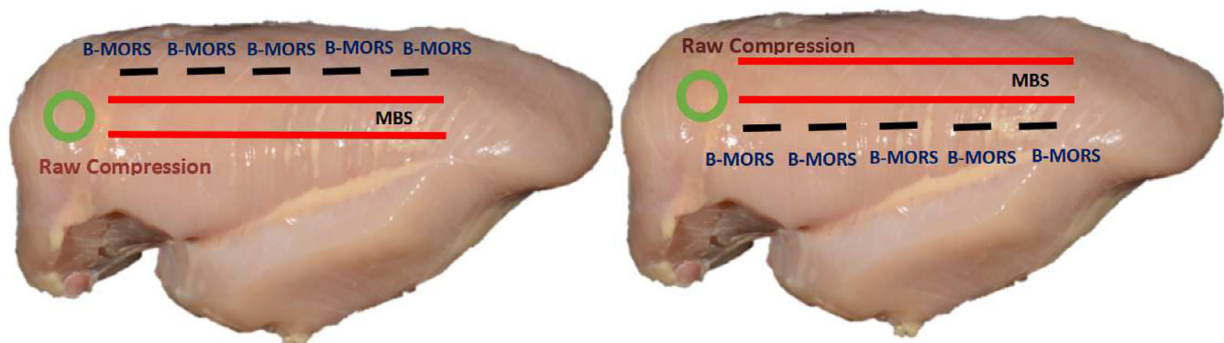Weight, drip loss, cook loss, color, pH, and raw compression force of the broiler breast fillets based on the

Figure 2. Location of razor shear measurements on broiler breast fillets.

WB condition are shown in Table 1. There were differences between the three WB groups for L* (= lightness) and pH values ($P < 0.10$). However, differences were noticed in fillet weight, drip loss, cook loss, white striping scores, a* (= redness), b* (= yellowness), and compression force values among the WB categories ($P < 0.05$). Average fillet weight, drip loss, and b* value of NOR were lower ($P < 0.05$) than either MOD or SEV fillets, which did not differ from each other ($P > 0.05$). Mean cook loss and white striping scores of NOR fillets were the lowest, those of the SEV fillets the highest, and MOD fillets intermediate. Average compression force and a* values of NOR fillets were lower ($P < 0.05$) than SEV fillets but not different ($P > 0.05$) from MOD fillets. There were no differences ($P > 0.05$) between SEV and MOD fillets on compression force and a* neither. Although the pH among the three WB groups was not different ($P < 0.05$), the pH of NOR was lower than MOD and SEV fillets ($P < 0.10$). The significant lower L* value was also noted in NOR samples compared to that in MOD ($P < 0.10$). On average, these results are consistent with the data published in the literature (Chatterjee et al., 2016; Tijare et al., 2016; Soglia et al., 2017; Dalgaard et al., 2018; Bowker and Zhuang, 2019). There are the differences in average pH and L* values between our data and the data in published reports. For example, average values of pH and L* of NOR in our study were larger than 6.00 and 60.0, respectively. However, they were less than 6.0 and 60.0, respectively, in published WB studies (Soglia et al., 2016; Tasoniero et al., 2016; Cai et al, 2017; Dalle Zotte et al., 2017; Chen et al., 2018). The differences in pH measurements could be partially due to the time when meat pH values were collected. In the most published data, it was collected at ≥24 h postmortem or ultimate pH value; however, it was measured at approximately 6 h postmortem in the present study. It has been demonstrated that the ultimate pH is consistently and significantly lower than the pH measured at early postmortem time (Glamoclija et al., 2015; Anadon, 2002. In addition,

both color and pH of poultry breast meat could be affected by many factors, including strains, gender, age, rearing practices/nutrients; preslaughter stress, primary processing technologies, postmortem handling, and even the methods/instruments and their settings used in the collection (Barbut, 1998; Fletcher, 1999; AMSA, 2012; Mir et al., 2017). One of the examples is that there are substantial variations in pH and color measurements of raw poultry breast meat (pectoralis major) among laboratories across the world in the published literature (Barbut, 1998; Petracci et al., 2004; Glamoclija et al., 2015). Our data confirmed that the selected breast fillets exhibited the characteristics of the normal and WB condition reported widely throughout the literature.

Raw Fillets Shear

Shear force measurements of raw fillets with different degrees of the WB condition are shown in Table 2. There were WB effects ($P < 0.001$) on the texture measurements; however, meat state (fresh/frozen) affected only MBS_E ($P < 0.05$). With the exception of MBS_E, none of the instrumental texture measurements of raw broiler breast exhibited a significant two-way interaction between WB condition and muscle state.

Both average BMORS_F and BMORS_E were greater ($P < 0.001$) in fillets with the WB myopathy (NOR < MOD < SEV). MBS_F values in MOD and SEV fillet samples and MBS_E in frozen raw MOD and SEV samples (MOD and SEV), which were not different from each other, were greater ($P < 0.001$) than those in NOR samples. However, there were differences ($P < 0.05$) between the three categories for MBS_E in the raw fresh samples. These results indicate that both BMORS and MBS methods are equivalent in their ability to separate different categories of the WB myopathy in fresh raw broiler fillets. However, the BMORS method performed better in separating WB categories in frozen, raw samples. Similar results for the BMORS method

Table 2. Shear force measurements of raw broiler breast fillets according to WB condition and meat state (LSmeans ± SD).

Trait/shear parameter			BMORS_F(N)	BMORS_E(N.mm)	MBS_F(N)	MBS_E(N.mm)
WB*State	NOR	Fresh	17.8 ± 1.5	151 ± 15	28.8 ± 3.1	340 ± 36[d]
		Frozen/Thawed	15.9 ± 3.3	146 ± 34	27.4 ± 6.8	366 ± 78[cd]
	MOD	Fresh	30.3 ± 1.5	272 ± 15	44.7 ± 3.1	522 ± 36[bc]
		Frozen/Thawed	32.0 ± 2.9	287 ± 31	52.1 ± 6.2	789 ± 72[a]
	SEV	Fresh	44.3 ± 1.5	417 ± 15	63.7 ± 3.1	746 ± 36[a]
		Frozen/Thawed	41.4 ± 2.9	385 ± 31	55.5 ± 6.2	740 ± 72[ab]
WB	NOR		16.8 ± 1.8[c]	148 ± 19[c]	28.1 ± 3.8[b]	353 ± 43
	MOD		31.2 ± 1.6[b]	280 ± 17[b]	48.4 ± 3.5[a]	656 ± 40
	SEV		42.8 ± 1.6[a]	401 ± 17[a]	59.6 ± 3.5[a]	743 ± 40
State	Fresh		30.8 ± 0.9	280 ± 9	45.7 ± 1.8	536 ± 21
	Frozen/Thawed		29.8 ± 1.8	273 ± 18	45.0 ± 3.7	632 ± 43
WB			***	***	***	***
State			NS	NS	NS	*
WB*State			NS	NS	NS	*

Abbreviations: NOR, no woody breast; MOD, moderate woody breast; SEV, severe woody breast; NS, not significant.
[a-d]LSmeans with different superscripts are different.
*$P < 0.05$. **$P < 0.01$. ***$P < 0.001$.

Table 3. Correlation coefficients between WB scores and shear measurements and between different shear measurements in raw broiler breast meat.

Parameter	WB[1]	BMORS_F[2]	BMORS_E[2]	MBS_F[2]	MBS_E[2]
WB[1]	1	0.63***	0.63***	0.71***	0.70***
BMORS_F[2]		1	0.95***	0.82***	0.79***
BMORS_E[2]			1	0.80***	0.80***
MBS_F[2]				1	0.82***
MBS_E[2]					1

[1]Spearman correlation coefficient.
[2]Pearson correlation coefficient.
***$P < 0.001$.

Table 4. Coefficients of variation in shear measurements of raw fillets in different WB categories.

WBC	N[1]	BMORS_F	BMORS_E	MBS_F	MBS_E
Fresh, never frozen					
NOR	24	0.43	0.38	0.31	0.36
MOD	24	0.49	0.52	0.43	0.37
SEV	24	0.39	0.43	0.28	0.29
Frozen/Thawed					
NOR	6	0.2	0.2	0.07	0.07
MOD	6	0.37	0.3	0.25	0.24
SEV	6	0.29	0.27	0.21	0.19

Abbreviations: NOR, no woody breast; MOD, moderate woody breast; SEV, severe woody breast.
[1]Number of the fillets.

were reported for WB fillets by Bowker and Zhuang (2019). The increased shear values observed in raw WB fillets could be due to increased connective tissue accumulation on the ventral surface of the fillets (Sihvo et al., 2014; Soglia et al., 2016).

The Spearman's correlation coefficients (r_s) between shear measurements and WB scores and Pearson's correlation coefficients (r) between different shear measurements are presented in Table 3. Spearman's correlation coefficients (r_s) showed that MBS measurements (including both peak force and shear energy) were more strongly related to the WB scores ($r_s = 0.70$ to 0.71) than BMORS measurements ($r_s = 0.63$) in raw breast fillets, although they were all different from zero ($P < 0.001$). As expected, Pearson's correlation between the shear measurements were statistically significant and strongly correlated (r = 0.79 to 0.95, $P < 0.001$). This observation highlights that both shear methods are good predictors of the raw shear values obtained for chicken breast fillets.

Coefficients of variation (CV) of raw breast fillets with the WB myopathy are shown in Table 4. Overall, the MBS data had consistently lower CV values regardless of the degree of the WB myopathy (MOD or SEV) and raw meat state. These results indicate that MBS measurements are more precise than BMORS measurements in raw breast meat.

Cooked Fillet Shear

LSmeans for the shear measurements of cooked broiler breast fillets with the WB myopathy are shown in Table 5. There were effects ($P < 0.001$) of the WB myopathy on all of the texture measurements. Meat state also ($P < 0.05$) affected all of the shear measurements except for BMORS_F. Two-way interactions ($P > 0.05$) were not observed between the WB myopathy and meat state (fresh vs. frozen-thawed) in cooked breast fillets.

MBS and BMORS shear values (including both peak shear force and shear energy) were greater ($P < 0.001$) in SEV fillets compared to those in NOR and MOD fillets, which were similar ($P > 0.05$). For MBS_E, there was a difference ($P < 0.05$) between SEV and NOR; however, no differences ($P > 0.05$) were observed between SEV and MOD or between MOD and NOR samples. These data suggested that in cooked fillets both MBS and BMORS methods were able to differentiate SEV from NOR and MOD; however, neither of them can separate NOR from MOD. Bowker and Zhuang (2019) reported that both BMORS_F and _E values of SEV were higher ($P < 0.001$) than those of NOR and MOD, which were not different from each other, in cooked frozen-thawed samples.

Table 5. Shear measurements of cooked broiler breast fillets according to WB condition and meat state (LSmeans ± SD).

Trait/shear parameter			BMORS_F(N)	BMORS_E(N.mm)	MBS_F(N)	MBS_E(N.mm)
WB*State	NOR	Fresh	15.0 ± 0.5	172 ± 5	88.1 ± 3.3	711 ± 30
		Frozen/Thawed	16.3 ± 1.0	184 ± 10	96.3 ± 6.6	764 ± 60
	MOD	Fresh	15.7 ± 0.5	174 ± 5	89.8 ± 3.3	742 ± 30
		Frozen/Thawed	17.2 ± 1.0	201 ± 10	110.0 ± 6.6	924 ± 60
	SEV	Fresh	18.6 ± 0.5	211 ± 5	101.3 ± 3.3	822 ± 30
		Frozen/Thawed	18.6 ± 1.0	219 ± 10	124.3 ± 6.6	1006 ± 60
WB	NOR		15.6 ± 0.6[b]	178 ± 6[b]	92.2 ± 3.7[b]	738 ± 33b
	MOD		16.5 ± 0.6[b]	188 ± 6[b]	99.9 ± 3.7[b]	833 ± 33[ab]
	SEV		18.6 ± 0.6[a]	215 ± 6[a]	112.8 ± 3.7[a]	914 ± 33[a]
State	Fresh		16.5 ± 0.3	186 ± 3[a]	93.1 ± 1.9[b]	758 ± 17[b]
	Frozen/Thawed		17.4 ± 0.6	201 ± 6[a]	110.2 ± 3.8[a]	898 ± 35[a]
WB			***	***	***	**
State			NS	*	***	***
WB* State			NS	NS	NS	NS

Abbreviations: NOR, no woody breast; MOD, moderate woody breast; SEV, severe woody breast; NS, not significant.
[a,b]LSmeans with different superscripts differ ($P < 0.05$).
*$P < 0.05$. **$P < 0.01$. ***$P < 0.001$.

Table 6. Correlation coefficients between the WB scores and shear measurements and between different shear measurements in cooked broiler breast fillet.

Parameter	WB[1]	BMORS_F[2]	BMORS_E[2]	MBS_F[2]	MBS_E[2]
WB[1]	1	0.26***	0.27***	0.35***	0.33**
BMORS_F[2]		1	0.92***	0.55***	0.45***
BMORS_E[2]			1	0.63***	0.52***
MBS_F[2]				1	0.93***
MBS_E[2]					1

[1]Spearman correlation coefficient.
[2]Pearson correlation coefficient.
**$P < 0.01$. ***$P < 0.001$.

Shears values for cooked broiler breast fillets were also affected by meat state (fresh never-frozen vs. frozen/thawed). Shear measurements of cooked frozen/thawed samples were greater ($P < 0.05$) than those of cooked, never-frozen samples for parameters MBS_F, MBS_E, and BMORS_E, although there was no difference in BMORS_F ($P > 0.05$). Bowker and Zhuang (2019) also found that meat state influenced the relationships between BMORS measurements and severity of the WB condition in cooked broiler breast meat.

Spearman's correlation coefficients (r_s) between shear measurements and WB condition and Pearson's correlation coefficients (r) between different shear measurements are presented in Table 6 for cooked broiler breast fillets. There were significant, but weak correlations ($r_s = 0.26$ to 0.35; $P < 0.01$) between shear measurements and the WB scores regardless of shear parameter, although MBS parameters showed slightly greater correlations ($r_s = 0.33$-0.35) than BMORS parameters ($r_s = 0.26$ to 0.27). Pearson's correlation between the four parameters was also significant ($P < 0.001$). Very strong correlations (r > 0.90) were observed between the two parameters within the shear method.

Coefficients of variation (CV) of shear measurements of cooked fillets with the WB myopathy are shown in Table 7. CV values of the MBS measurements were either similar to that of the BMORS measurements (frozen/thawed NOR samples) or lower than those of the BMORS measurements. These results indicate that MBS measurements were either as precise as or more precise than BMORS measurements in cooked broiler breast fillets with the WB myopathy.

Table 7. Coefficients of variation in shear measurements of cooked broiler fillets in different WB categories.

WB/Shear Parameter	N[1]	BMORS_F	BMORS_E	MBS_F	MBS_E
Fresh					
NOR	24	0.17	0.14	0.16	0.18
MOD	24	0.30	0.28	0.16	0.16
SEV	24	0.32	0.30	0.19	0.22
Frozen/Thawed					
NOR	6	0.33	0.24	0.18	0.19
MOD	6	0.36	0.30	0.19	0.18
SEV	6	0.23	0.21	0.09	0.13

Abbreviations: NOR, no woody breast; MOD, moderate woody breast; SEV, severe woody breast.
[1]Number of the fillets.

In addition to the direct comparisons of the two shear methods previously discussed, several particular phenomenon from the present study should also be noted. One of them is that cooking had effect ($P < 0.05$) on MBS and BMORS measurements regardless of shear parameter (either force or energy). MBS measurements were consistently higher in cooked samples compared to those in raw samples regardless of the WB myopathy degree (MOD or SEV). However, BMORS measurements of cooked fillets with the WB myopathy (both MOD and SEV) were consistently lower than those of raw fillets. This difference could be attributed to the shear mechanisms of the two different blades. MBS is equipped with multiple sharp blades; while the BMORS method utilizes a single blunt blade. Similar to the MORS method which uses a single sharpened razor blade, the MBS method likely measures primarily the force required to shear through the muscle fibers. However, measurements using the BMORS method are thought to reflect a combination of both compression force and shear force measurements of muscle due to the blunted razor blade. The same relationship was reported by Bowker and Zhuang (2019) and Chatterjee et al. (2016). These results indicate that cooking or heat denaturation of muscle proteins enhances strength of muscle fibers to resist shear of both normal and WB meat; however, cooking significantly reduces the resistance of raw broiler breast fillets with the WB myopathy to compression force.

The Spearman's correlations between the shear measurements and the WB myopathy scores were much stronger in the raw state than those in cooked state regardless of shear method (MBS or BMORS) and parameter. This finding is consistent with previously published data (Bowker and Zhuang, 2019), further demonstrating that texture differences between NOR and WB meat (including both MOD and SEV) are more evident in raw meat than in cooked meat.

In addition, data from this study also demonstrate that MBS measurements are either equivalent to or more precise than BMORS measurements of broiler breast meat with the WB myopathy regardless of raw meat state (never-frozen or frozen/thawed), meat cooking state, or shear parameter.

CONCLUSION

The MBS method can be used for both raw and cooked chicken breast meat with minimal sample preparation before shear, similarly to the MORS and BMORS methods. The advantages of the MBS method include that it works either as well as or better than BMORS method in characterizing tactile properties of broiler breast meat with the WB myopathy and correlating texture measurements with severity of the WB myopathy (or predicting the WB) in broiler fillets regardless of meat state (fresh never-frozen vs. frozen-thawed and raw vs. cooked) and the shear parameter (force or energy). With the MBS method, only one shear

measurement is required compared to at least four measurements using the conventional razor blade methods (MORS and BMORS). Data indicate that MBS measurements are, overall, more precise than the razor blade methods. Therefore, the MBS method could be a good alternative for texture measurements of broiler breast meat with the WB myopathy. Since either MORS or BMORS are increasingly used as a routine method in measuring texture quality and predicting tenderness of cooked normal poultry breast meat, the application of this new MBS method for predicting poultry meat tenderness should be further explored.

ACKNOWLEDGMENT

DISCLOSURES

The authors declare no conflicts of interest.

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