黑燕麥在不同收穫期之芻料產量、品質及青貯調製研究 (1)

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摘 要

本研究利用環境適應性較佳之黑燕麥 (*Avena strigosa* Schreb.) 作為冬季芻料，研究不同收穫期對其產量、品質與青貯調製之影響。自孕穗期開始，隨著收穫期愈晚，黑燕麥的乾物率及產量愈高，分別由 15.6%、5.37 ton/ha 增加至 45.5%、10.54 ton/ha。然而，芻料品質卻隨著收穫期愈晚而愈差，粗蛋白質及水溶性碳水化合物含量分別自 20.8%、6.7% 降至 12.8%、5.0%，酸洗纖維及中洗纖維含量分別自 37.8%、52.4% 增加至 43.5%、63.6%。不同收穫期之乾物率及芻料營養組成影響青貯調製與品質，播種後 93 天收穫之黑燕麥不論有無添加乳酸菌均能製成良好青貯，播種後 119 天收穫之黑燕麥則因乾物率較高且水溶性碳水化合物含量較低而限制青貯發酵生成乳酸，需添加乳酸菌才能製成品質良好之青貯。在乾物率適當且相同收穫期之下，隨著萎凋時間由 1 至 29.5 小時，黑燕麥之乾物率愈高，碳水化合物含量則在不同萎凋時間有所起伏，但粗蛋白質及纖維含量變化不大。不添加乳酸菌下，隨著萎凋時間愈長，青貯發酵產生之乳酸含量愈低，但均能製成良好青貯。添加乳酸菌下，不同萎凋時間之青貯乳酸含量均顯著提升，達到優良等級之青貯品質。

關鍵詞：燕麥、收穫期、芻料品質、青貯。

緒 言

燕麥為一年生禾本科植物，是全球產量排行第六的穀類作物 (FAO, 2014)。由於穀粒富含蛋白質、纖維及礦物質，燕麥既是有益於人體健康的糧食，也是高營養價值的動動飼糧 (Cuddeford, 1995; Bae *et al.*, 2010)，全株亦可作為動物用的乾草、青貯料、墊料及放牧草地 (Contreras-Govea and Albrecht, 2006; Ahmad *et al.*, 2014)。燕麥屬 (Avena) 作物依染色體組可分為二倍體、四倍體及六倍體，多數為野生品種，穀粒用栽培品種主要為六倍體的普通燕麥 (*Avena sativa* L.) 與紅燕麥 (*Avena byzantina* L.)，此兩品種也可作為芻料；此外，二倍體的黑燕麥 (*A. strigosa* Schreb.) 亦常作為芻料 (曾，1994; Kim *et al.*, 2014)。普通燕麥適合生長於氣候冷涼、較為潮溼之地區，對高溫及乾旱敏感，尤其抽穗後至成熟期若遇乾熱天氣將造成結實不佳而影響產量；相較於普通燕麥，紅燕麥及黑燕麥對於高溫及乾旱的耐受性較強 (Stevens *et al.*, 2004)。

燕麥作為芻料的產量與品質受到品種、播種期及收穫期等因素之影響。在播種期相同之下，芻料用燕麥的產量高於穀粒用燕麥，晚熟型品種的產量高於早熟型，又品種特性不同亦會造成芻料品質的差異 (Coblentz *et al.*, 2011; Coblentz *et al.*, 2012)。在不同季節播種，燕麥會因生育期的氣候變化不同而造成產量與品質差異。在溫帶地區，春季播種的燕麥較夏或秋季播種的產量高，但夏或秋季播種的燕麥在生殖生長階段氣候較為冷涼，因此其芻料品質較春季播種者為佳 (Contreras-Govea and Albrecht, 2006; Kim *et al.*, 2006)。在燕麥完全成熟前，隨著收穫期愈晚產量愈高。然而，收穫期愈晚會使植株的成熟度愈高，造成燕麥的纖維含量增加、粗蛋白質含量及總可消化養分降低而影響芻料品質 (Coblentz *et al.*, 2011; Coblentz *et al.*, 2012; Coblentz *et al.*, 2014)。燕麥的成熟度亦會影響青貯品質，綜合考量產量、發酵後產物、營養價值及動物採食量，糊熟前期 (early dough stage) 是燕麥製作青貯較理想的成熟度 (Nadeau, 2007; Wallsten *et al.*, 2008; Wallsten *et al.*, 2010)。此外，青貯調製過程加入有機酸、糖蜜、纖維分解酵素或微生物菌劑等添加劑，有助於提升燕麥青貯品質 (Shao *et al.*, 2005; Khan *et al.*, 2006; Nadeau, 2007)。

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為了發展酪農業，燕麥過去曾為臺灣冬季主要青刈芻料作物之一。然而，隨著大量水田轉作盤固草及水旱田利用調整計畫，燕麥栽培面積大幅下降，酪農轉而依賴進口燕麥且需求日益增加 (曾，1994)。黑燕麥由於株型直立、分蘗性佳、營養價值及消化率高，在美國南部、澳洲與南美洲常作為芻料利用。此外，由於對高溫和乾旱的耐受性較強，黑燕麥亦適合於亞熱帶地區栽培，作為草食動物的冬季芻料 (Salgado *et al.*, 2010; Restelatto *et al.*, 2013)。受到冷涼、潮溼之氣候影響，臺灣普遍栽培的熱帶性牧草在冬季幾乎無法生產，造成芻料供應短缺，尤以中、北部地區為甚。為了增加芻料來源與降低進口依賴性，本試驗以不同收穫期的黑燕麥，研究其芻料產量、品質及青貯調製，作為日後生產之參考。

材料與方法

I. 栽培及收穫

以黑燕麥品系 Saia (*Avena strigosa* Schreb., cv. Saia) 作為試驗材料，在 2014 年 11 月 24 日種植於畜試所恆春分所試驗區，小區面積 8 m × 4 m，三重複，行距 15 cm，每公頃播種 80 公斤種子，採條播方式種植。試驗田區以臺肥 1 號複合肥料 (N：P_2O_5：K_2O = 20：5.5：10；每公頃施用 100 kg) 作為基肥，不施用追肥，利用中耕培土及人工除草進行雜草防除。自黑燕麥成熟度達孕穗期 (boot stage) 後，分別於播種後 74、93、105 及 119 天進行收穫，每小區刈割 1 m^2，供產量估算、植體成分測定及後續之青貯試驗。

II. 植體成分測定

不同收穫期及青貯前的黑燕麥進行取樣，樣品經 80℃烘乾 48 小時後磨粉，分析燕麥之粗蛋白質 (crude protein, CP)、酸洗纖維 (acid detergent fiber, ADF)、中洗纖維 (neutral detergent fiber, NDF) 及水溶性碳水化合物 (water soluble carbohydrates, WSC) 含量。分析方法如下：依 Kjeldahl 法 (A.O.A.C., 1990) 測定植體全氮含量後乘以 6.25 即得 CP，ADF 及 NDF 的測定以 $ANKOM^{200}$ 纖維分析儀進行 (Komarek *et al.*, 1996; Vogel *et al.*, 1999)，NDF 採添加 α-amylase 之方法 (Van Soest *et al.*, 1991)。WSC 測定以 80% 酒精萃取樣品乾粉，混合萃取液並除去酒精後定量，依蒽酮 (anthrone) 呈色法測定 (Morris, 1948)。

III. 青貯試驗

(i) 不同收穫期之青貯試驗

播種後 93 天收穫之黑燕麥經 24 小時萎凋後青貯，播種後 119 天收穫之黑燕麥經 5 小時萎凋後青貯，作為不同收穫期之青貯試驗。

(ii) 不同萎凋時間之青貯試驗

播種後 105 天收穫之黑燕麥，分別經 1、3.5、25、29.5 小時萎凋後青貯，作為不同萎凋時間之青貯試驗。

青貯試驗之黑燕麥均為全株收穫，經萎凋後由機械細切至 2 － 5 cm，分為兩種青貯處理，對照組：青貯時無菌劑接種；接種組：青貯時接種自行分離之乳酸菌劑 (*Lactobacillus plantarum* subsp. *plantarum* 及 *Lactobacillus casei* 混合菌劑，接種量為 2 × 10^8 cfu/kg 材料鮮重)。黑燕麥處理後混合均勻密封於真空塑膠袋內，每袋裝填 1 kg，每種處理二重複，於室溫下存放 50 天後開封，測定青貯發酵品質。

IV. 青貯品質測定

青貯前的黑燕麥進行取樣，經 80℃烘乾 48 小時後計算乾物率。青貯開封後之酸鹼值為 20 g 青貯料加水 180 mL，打碎過濾後以酸鹼度計測定之值。乳酸、乙酸、丙酸及丁酸之測定以氣體層析儀依 Jones and Kay (1976) 的方法進行。計算青貯中乳酸、乙酸及丁酸各佔所測定乳酸、乙酸、丙酸及丁酸四者總量之當量百分比，將三項數值依評分公式加總後即為青貯品質評分 (Flieg’s score)，40 分以下表示青貯失敗、40 － 60 分為可接受、60 － 80 分為好的青貯、80 分以上為發酵優良的青貯。

結果與討論

黑燕麥在成熟度達孕穗期時開始收穫，隨著收穫期愈晚，植株的乾物率愈高，乾物質產量也由 5.37 ton/ha 增加至 10.54 ton/ha (表 1)。在芻料品質部份，隨著收穫期愈晚，黑燕麥 CP 由 20.8% 下降至 12.8%，ADF 及 NDF 分別由 37.8%、52.4% 增加至 43.5%、63.6%，WSC 則由 6.7% 下降至 5.0% (表 2)，顯示當收穫期愈晚，易消化之養分含量漸減，不易消化之纖維含量漸增而導致芻料品質下降。在相同品種與播種期之下，收穫期愈晚即植株成熟度愈高，燕麥之乾物質累積愈多而產量愈高 (Coblentz and Walgenbach, 2010; Coblentz *et al.*, 2011; Coblentz *et al.*, 2014)。

然而，當燕麥成熟度達完熟期後，收穫期愈晚葉片老化的比例愈高，產量反而降低 (Coblentz *et al.*, 2011)。當收穫期愈晚，燕麥之芻料品質愈低，ADF、NDF 及木質素含量愈高，CP 含量、NDF 消化率及乾物質消化率愈低 (Coblentz *et al.*, 2000; Coblentz *et al.*, 2012)。此外，燕麥的芻料品質會隨著收穫季節氣候不同而異。春播燕麥的收穫期在夏季，因此收穫期愈晚，植株成熟度會隨著氣溫漸增而纖維含量愈高。夏末播種的燕麥因生育後期氣溫漸降，收穫期愈晚，WSC 含量會漸增而提升植株對低溫的耐受性 (Contreras-Govea and Albrecht, 2006; Coblentz and Walgenbach, 2010)。本研究之黑燕麥由於收穫期自 2 月上旬至 3 月下旬，隨著收穫期愈晚，在植株成熟度及氣溫均增加的影響下，芻料產量愈高但品質愈不理想。

以不同收穫期之黑燕麥進行青貯，青貯前材料之乾物率及芻料化學成分如表 3。播種後 93 天收穫之黑燕麥由於收穫時的植株成熟度較嫩、含水率較高，經萎凋 24 小時後乾物率才達到適合青貯製作之標準。芻料經由適度的萎凋可提升青貯品質，但隨著萎凋的時間愈長，易消化營養成分受到植體及微生物呼吸作用的消耗愈多 (Rotz and Muck, 1994)。播種後 93 天收穫的材料雖經過較長時間之萎凋，播種後 119 天收穫時之氣溫與植株成熟度顯著高於播種後 93 天，導致播種後 93 天仍較 119 天收穫之黑燕麥乾物率低、CP 及 WSC 含量高、ADF 及 NDF 含量低。

表 1.　黑燕麥在不同收穫期之乾物率及乾物產量

Table 1.　Dry matter content and dry matter yield of black oat harvested on different dates

Harvest date	Days after planting	Dry matter content (%)	Dry matter yield (ton/ha)
2015.2.6	74	15.6[d]	5.37[c]
2015.2.25	93	17.0[c]	5.93[c]
2015.3.9	105	25.3[b]	6.79[b]
2015.3.23	119	45.5[a]	10.54[a]

[a, b, c, d] Means within a column followed by the different letters are significantly different at 5% level by Fisher's protected LSD test.

表 2.　黑燕麥在不同收穫期之芻料化學成分

Table 2.　Forage chemical components of black oat harvested on different dates

DAP†	CP	ADF	NDF	WSC
	------------	------------ %	------------	------------
74	20.8[a]	37.8[b]	52.4[d]	6.7[a]
93‡	21.1[a]	38.9[b]	57.1[c]	5.3[b]
105	17.9[b]	38.5[b]	59.5[b]	5.2[bc]
119	12.8[c]	43.5[a]	63.6[a]	5.0[c]

† DAP, CP, ADF, NDF, and WSC were days after planting, crude protein, acid detergent fiber, neutral detergent fiber, and water soluble carbohydrates, respectively. (on a dry matter basis)

‡ The forage chemical components were black oat wilted one day after cut on 93 DAP.

[a, b, c, d] Means within a column followed by the different letters are significantly different at 5% level by Fisher's protected LSD test.

表 3.　黑燕麥在不同收穫期之青貯前乾物率及芻料化學成分

Table 3.　Dry matter content and forage chemical components of black oat harvested on different dates before ensiling

DAP†	DM	CP	ADF	NDF	WSC
	------------	------------	------------ %	------------	------------
93‡	35.8[b]	21.1[a]	38.9[b]	57.1[b]	5.3[a]
119	55.9[a]	13.7[b]	48.0[a]	63.5[a]	4.7[b]

† DAP, DM, CP, ADF, NDF, and WSC were days after planting, dry matter content, crude protein, acid detergent fiber, neutral detergent fiber, and water soluble carbohydrates, respectively. (on a dry matter basis)

‡ Black oat of 93 and 119 DAP were wilted 24 and 5 hours, respectively.

[a, b] Means within a column followed by the different letters are significantly different at 5% level by Fisher's protected LSD test.

黑燕麥青貯的發酵產物與品質因收穫期及有無乳酸菌接種而異 (表 4)。播種後 93 天收穫所調製之青貯不論有無接種乳酸菌，兩種處理之 pH、乙酸、丙酸、丁酸及乳酸含量、青貯品質均不具差異。此外，未接種乳酸菌處理下，播種後 93 天收穫所調製之青貯 pH 較播種後 119 天低，兩收穫期之丙酸及丁酸含量不具差異，但播種後 93 天之乙酸及乳酸含量均高於播種後 119 天，青貯品質以播種後 93 天較佳。青貯發酵的優劣決定於植體特性 (乾物率、營養組成及酸鹼緩衝能力)、發酵環境 (裝填紮實度及密封程度) 與植株表面菌相等因素，植株乾物率過高、碳水化合物含量較低或酸鹼緩衝能力過強均會限制青貯發酵，造成產酸量低、pH 不易下降而影響青貯品質 (Rotz and Muck, 1994; Kung and Shaver, 2001)。相較於播種後 93 天收穫進行青貯之黑燕麥，播種後 119 天之植株乾物率偏高且 WSC 較低 (表 3)，未接種乳酸菌處理下，播種後 119 天之青貯不利於微生物發酵，導致其乙酸及乳酸含量低而 pH 較高、青貯品質較差。反觀播種後 93 天收穫之黑燕麥經萎凋後，在適當的乾物率及 WSC 含量下，其發酵的產酸量不論有無乳酸菌接種均較播種後 119 天高，青貯品質亦均屬良好 (表 4)。由試驗結果可知，不同收穫期之乾物率及營養組成是影響黑燕麥青貯成敗的主因，可藉由乳酸菌之添加來提升青貯品質。

表 4. 黑燕麥在不同收穫期及接種處理之青貯發酵產物與品質評分

Table 4. Silage fermentation products and quality of black oat harvested on different dates and inoculation treatments

DAP†	pH		A		P		B		L		Score	
			%									
	CK‡	I	CK	I	CK	I	CK	I	CK	I	CK	I
93	4.9[bA]	5.2[aA]	1.9[aA]	2.7[aA]	0.06[aA]	0.06[aA]	0.02[aA]	0.01[aA]	3.0[aA]	2.7[aA]	75[aA]	64[bA]
119	6.1[aA]	4.8[aB]	0.2[bA]	0.8[bA]	0.07[aA]	0.05[aA]	0.01[aA]	0.02[aA]	0.2[bB]	2.5[aA]	53[bB]	88[aA]

† DAP, A, P, B, and L were days after planting, acetic acid, propionic acid, butyric acid, and lactic acid, respectively. (on a dry matter basis)

‡ CK and I were without and with inoculation, respectively.

a, b, A, B Means within a column (in small letter) and within a row (in capital letter) followed by the different letter(s) are significantly different at 5% level by Fisher's protected LSD test.

由於乾物率及 WSC 含量不同，燕麥的成熟度會造成青貯品質差異 (Wallsten *et al.*, 2010)。相較於其他燕麥青貯研究，播種後 119 天進行青貯調製的黑燕麥 WSC 含量並不算低，但乾物率明顯偏高 (Nadeau, 2007; Wallsten *et al.*, 2010)。較高的乾物率會限制燕麥青貯發酵，可藉由微生物菌劑及有機酸的添加，使發酵後的乳酸含量提升並降低 pH 以抑制雜菌，進而改善青貯品質 (Nadeau, 2007)。透過接種乳酸菌，播種後 119 天青貯之乳酸含量較未接種者大幅提升，品質亦顯著優於未接種者及播種後 93 天以乳酸菌接種之青貯 (表 4)。

以乾物率適當、播種後 105 天收穫之黑燕麥，在不同萎凋時間進行青貯，青貯前材料之乾物率及營養組成如表 5。隨著萎凋時間愈長，黑燕麥之乾物率愈高。在營養組成方面，CP 含量除了萎凋 3.5 小時較低，其餘萎凋時間之含量差異不大；ADF 及 NDF 含量不隨著萎凋時間增加而產生差異；WSC 含量以萎凋 3.5 及 25 小時較高，29.5 小時次之，1 小時之含量最低。芻料萎凋過程中營養組成之變化受到植體及微生物的呼吸作用影響，其中主要是 WSC 含量的變動，CP、ADF、NDF 與木質素等含量差異不大 (Rotz and Muck, 1994)。萎凋除了呼吸作用消耗 WSC，亦會水解澱粉產生 WSC。受到呼吸作用和澱粉水解的綜合效應，芻料萎凋後的 WSC 含量可能變化不大甚至增加，但萎凋時間愈長，澱粉及 WSC 含量下降愈顯著 (Owens *et al.*, 1999; Cavallarin *et al.*, 2005; Liu *et al.*, 2011)。黑燕麥萎凋 3.5、25 及 29.5 小時之 WSC 含量較萎凋 1 小時高，推測是澱粉水解生成的 WSC 多於呼吸作用所消耗。此外，萎凋 29.5 小時之 WSC 含量低於萎凋 25 小時，若萎凋時間再延長，WSC 含量應愈低。

不同萎凋時間除了影響黑燕麥之乾物率及營養組成，亦影響青貯的發酵產物與品質 (表 6)。黑燕麥未接種乳酸菌處理下，pH 以萎凋 25 小時最高、1 小時最低，不同萎凋時間之丙酸及丁酸含量無顯著差異。隨著萎凋時間愈長，乙酸含量愈低。乳酸含量除了萎凋 25 小時特別低之外，亦隨著萎凋時間延長而含量降低。青貯品質僅萎凋 25 小時較低，其餘均為優良等級，又以萎凋 1 及 3.5 小時最佳。黑燕麥不同萎凋時間之青貯結果與其他芻料相近，隨著萎凋時間愈長，丙酸及丁酸含量變化不大，但乙酸及乳酸含量愈低 (Cavallarin *et al.*, 2005; Liu *et al.*, 2011)。萎凋 25 小時青貯前之黑燕麥乾物率及營養組成介於萎凋 3.5、29.5 小時之間 (表 5)，但其青貯之乳酸含量顯著偏低而使品質大幅差於萎凋 3.5 及 29.5 小時，推測可能是青貯調製之材料取樣偏差，造成表面菌相差異而影響青貯發酵產物及品質。

表 5.　黑燕麥經不同萎凋時間後青貯前之乾物率及芻料化學成分

Table 5.　Dry matter content and forage chemical components of black oat wilted for different hours before ensiling

Wilted hours†	DM‡	CP	ADF	NDF	WSC
	%				
1	33.7^{d}	15.4^{ab}	41.3^{a}	62.1^{a}	3.7^{c}
3.5	38.5^{c}	14.4^{b}	41.9^{a}	61.5^{a}	5.1^{a}
25	43.5^{b}	15.1^{ab}	42.8^{a}	62.5^{a}	5.3^{a}
29.5	46.2^{a}	16.0^{a}	41.0^{a}	59.9^{a}	4.7^{b}

† 1, 3.5, 25, and 29.5 were black oat harvested DAP on 105 and wilted for 1, 3.5, 25, and 29.5 hours, respectively.

‡ DM, CP, ADF, NDF, and WSC were the same as table 3

[a, b, c, d] Means within a column followed by the different letter(s) are significantly different at 5% level by Fisher's protected LSD test.

表 6.　黑燕麥經不同萎凋時間及接種處理之青貯發酵產物與品質評分

Table 6.　Silage fermentation products and quality of black oat wilted for different hours and inoculation treatments

Wilted hours†	pH		A‡		P		B		L		Score	
			%									
	CK	I	CK	I	CK	I	CK	I	CK	I	CK	I
1	4.1^{dA}	3.9^{bB}	0.8^{aA}	0.8^{aA}	0.08^{aA}	0.01^{bA}	0.03^{aA}	0.02^{aA}	4.6^{aA}	4.8^{aA}	96^{aA}	95^{aA}
3.5	5.0^{cA}	4.0^{abB}	0.5^{bA}	0.6^{abA}	0.06^{aA}	0.04^{bA}	0.03^{aA}	0.01^{aA}	1.8^{bB}	4.8^{aA}	91^{aB}	98^{aA}
25	6.1^{aA}	4.3^{abB}	0.4^{bcA}	0.7^{abA}	0.11^{aA}	0.09^{aA}	0.02^{aA}	0.01^{aA}	0.4^{dB}	3.8^{abA}	61^{cB}	99^{aA}
29.5	5.4^{bA}	4.4^{aB}	0.3^{cA}	0.4^{bA}	0.12^{aA}	0.09^{aA}	0.04^{aA}	0.01^{aA}	1.2^{cB}	3.1^{bA}	81^{bB}	99^{aA}

† 1, 3.5, 25, and 29.5 were the same as table 5.

‡ A, P, B, L, CK and I were the same as table 4.

[a, b, c, d, A, B] Means within a column (in small letter) and within a row (in capital letter) followed by the different letter(s) are significantly different at 5% level by Fisher's protected LSD test.

在乳酸菌添加下，隨著萎凋時間增加，黑燕麥青貯之 pH 及丙酸含量漸增，乙酸及乳酸含量漸低，但丁酸含量則不因萎凋時間長短而有所差異，不同萎凋時間之黑燕麥均有極優良之青貯品質 (表 6)。比較有無添加乳酸菌對不同萎凋時間青貯的影響，兩者之乙酸、丙酸及丁酸含量無顯著差異，乳酸含量除萎凋 1 小時外均以有添加菌劑者較高，乳酸含量的增加使有添加菌劑之 pH 低於未添加者，乳酸菌添加之青貯品質除萎凋 1 小時外均顯著優於未添加者。適度萎凋除了提升芻料品質，亦有利於青貯調製 (Cavallarin *et al.*, 2005; Liu *et al.*, 2011)。當燕麥青貯條件不佳時，調製過程可藉由添加糖蜜、有機酸、纖維分解酵素或微生物菌劑來提升青貯品質 (Shao *et al.*, 2005; Khan *et al.*, 2006; Nadeau, 2007)。選擇適當之收穫期、萎凋程度與添加青貯菌劑，有助於黑燕麥作為品質良好之青貯。

結　　論

受限於氣候影響，臺灣普遍種植的熱帶性牧草無法於冬季生產，中、北部地區更不若南部可生產青割玉米與乾草，為維持芻料品質及供應穩定，大部份需投注較多成本自南部採買或仰賴進口乾草。黑燕麥可適應冷涼與潮溼的氣候，適合於冬季裡作作為芻料生產。然而，收穫期不同會影響黑燕麥的芻料產量與營養組成，選擇適當的收穫期與萎凋程度有利於青貯調製，亦可藉由乳酸菌劑之添加來確保青貯品質。

參考文獻

曾美倉。1994。燕麥。雜糧作物各論 I. 禾穀類。pp. 129-168。

A. O. A. C. 1990. Official methods of analysis. Vol. 1. 15th ed. AOAC, Arlington, VA. U.S.A.

Ahmad, M., Z. A. Gul-Zaffar and M. Habib. 2014. A review on oat (*Avena sativa* L.) as a dual-purpose crop. Sci. Res. Essays

9: 52-59.

Bae, I. Y., S. M. Kim, S. Lee and H. G. Lee. 2010. Effect of enzymatic hydrolysis on cholesterol-lowering activity of oat beta-glucan. N. Biotechnol. 27: 85-88.

Cavallarin, L., S. Antoniazzi, G. Borreani and E. Tabacco. 2005. Effects of wilting and mechanical conditioning on proteolysis in sainfoin (*Onobrychis viciffolia* Scop) wilted herbage and silage. J. Sci. Food Agric. 85: 831-838.

Coblentz, W. K. and R. P. Walgenbach. 2010. Fall growth, nutritive value, and estimation of total digestible nutrients for cereal-grain forages in the north-central United States. J. Anim. Sci. 88: 383-399.

Coblentz, W. K., K. P. Coffey, J. E. Turner, D. A. Scarbrough, J. S. Weyers, K. F. Harrison, Z. B. Johnson, L. B. Daniels, C. F. Rosenkrans Jr., D. W. Kellogg and D. S. Hubbell III. 2000. Effect of maturity on degradation kinetics of sod-seeded cereal grains in northern Arkansas. J. Dairy Sci. 83: 2499-2511.

Coblentz, W. K., M. G. Bertram and N. P. Martin. 2011. Planting date effects on fall forage production of oat cultivars in Wisconsin. Agron. J. 103: 145-155.

Coblentz, W. K., M. G. Bertram, N. P. Martin and P. Berzaghi. 2012. Planting date effects on the nutritive value of fall-grown oat cultivars. Agron. J. 104: 312-323.

Coblentz, W. K., W. E. Jokela and M. G. Bertram. 2014. Cultivar, harvest date, and nitrogen fertilization affect production and quality of fall oat. Agron. J. 106: 2075-2086.

Contreras-Govea, F. E. and K. A. Albrecht. 2006. Forage production and nutritive value of oat in autumn and early summer. Crop Sci. 46: 2382-2386.

Cuddeford, D. 1995 Oats for animal feed. In: Welch, R. W. ed. The oat crop; production and utilization. London: Chapman and Hall. 321-368.

Food and Agriculture Organization (FAO). 2014. http://faostat3.fao.org/.

Jones, D. W. and J. J. Kay. 1976. Determination of volatile fatty acid C1-C6 and lactic acid in silage juice. J. Sci. Food Agric. 27: 1005-1014.

Khan, M. A., M. Sarwar, M. Nisa, M. S. Khan, Z. Iqbal, W. S. Lee, H. J. Lee and H. S. Kim. 2006. Chemical composition, in situ digestion kinetics and feeding value of oat grass (*Avena sativa*) ensiled with molasses for Nili-Ravi Buffaloes. Asian-Aust. J. Anim. Sci. 19: 1127-1133.

Kim, J. D., S. G. Kim, S. J. Abuel, C. H. Kwon, C. N. Shin, K. H. Ko and B. G. Park. 2006. Effect of location, season, and variety on yield and quality of forage oat. Asian-Aust. J. Anim. Sci. 19: 970-977.

Kim, S. K., N. A. Tinker and M. A. Newell. 2014. Improvement of oat as a winter forage crop in the southern United States. Crop Sci. 54: 1336-1346.

Komarek, A. R., H. Manson and N. Thiex. 1996. Crude fiber determination using the ANKOM system. Publ. 102. ANKOM technol. Corp., Fairport, NY. U.S.A.

Kung, L. and R. Shaver. 2001. Interpretation and use of silage fermentation analysis reports. University of Wisconsin-Madison, USA. Focus Forage 3: 1-5.

Liu, Q., J. Zhang, S. Shi and Q. Sun. 2011. The effects of wilting and storage temperatures on the fermentation quality and aerobic stability of stylo silage. Anim. Sci. J. 82: 549-553.

Morris, D. L. 1948. Quantitative determination of carbohydrates with dry-wood's anthrone reagent. Science 107: 254-255.

Nadeau, E. 2007. Effects of plant species, stage of maturity and additive on the feeding value of whole-crop cereal silage. J. Sci. Food Agric. 87: 789-801.

Owens, V. N., K. A. Albrecht, R. E. Muck and S. H. Duke. 1999. Protein degradation and fermentation characteristics of red clover and alfalfa silage harvested with varying levels of total non-structural carbohydrates. Crop Sci. 39: 1873-1880.

Restelatto, R., P. S. Pavinato, L. R. Sartor and S. J. Paixão. 2013. Production and nutritional value of sorghum and black oat forages under nitrogen fertilization. Grass Forage Sci. 69: 693-704.

Rotz, C. A. and R. E. Muck. 1994. Changes in forage quality during harvest and storage. In: Forage quality, evaluation, and utilization, Eds. G. C. Fahey, Jr. *et al.* Am. Soc. Agron., Madison, WI. pp. 828-868.

Salgado, P., B. Le Hoa, V. T. Tran, C. Vu Chi, B. Faye and P. Lecomte. 2010. Identifying suitable temperate forage species and management strategies for the mountain regions of North Vietnam. Grass Forage Sci. 65: 110-120.

Shao, T., M. Shimojo, T. Wang and Y. Masuda. 2005. Effect of additives on the fermentation quality and residual mono-and disaccharides compositions of forage oats (*Avena sativa* L.) and Italian ryegrass (*Lolium multiflorum* Lam.) silages.

Asian-Aust. J. Anim. Sci. 18: 1582-1588.

Stevens, E. J., K. W. Armstrong, H. J. Bezar, W. B. Griffin and J. G. Hampton. 2004. Fodder oats: an overview. In: Suttie, J. M. and S. G. Reynolds. eds. Fodder Oats: A World Overview. Rome: Food and Agriculture Organization of the United Nations, pp. 1-9.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74: 3583-3597.

Vogel, K., J. F. Pedersen, S. D. Masterson and J. J. Toy. 1999. Evaluation of a filter bag system for NDF, ADF, and IVDMD forage analysis. Crop Sci. 39: 276-279.

Wallsten, J., J. Bertilsson, E. Nadeau and K. Martinsson. 2010. Digestibility of whole-crop barley and oat silages in dairy heifers. Animal 4: 432-438.

Wallsten, J., E. Nadeau, J. Bertilsson and K. Martinsson. 2008. Voluntary intake and diet selection by dairy heifers fed ensiled whole-crop barley and oats harvested at different stages of maturity. Livest. Sci. 122: 94-98.

Study on forage yield, quality and ensiling of black oat harvested on different days (1)

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Abstract

To examine the effect of forage yield, quality and ensiling on different harvest days, this study was conducted to use black oat (*Avena strigosa* Schreb.) as winter forage, which was widely adapted to various climatic conditions. From boot stage, with longer harvest days comes higher dry matter content and yield of black oat, from 15.6% and 5.37 ton/ha increase to 45.5% and 10.54 ton/ha, respectively. However, forage quality became worse as longer harvest days. The content of crude protein (CP) and water soluble carbohydrates (WSC) from 20.8% and 6.7% decrease to 12.8% and 5.0%, respectively. Besides, the content of acid- and neutral- detergent fiber from 37.8% and 52.4% increase to 43.5% and 63.6%, respectively. The ensiling and silage quality of black oat were affected by DM and nutrient contents for different harvest days. Black oat with or without lactic acid bacteria (LAB) inoculation would both be good quality silage by harvest of 93 days after planting. However, higher DM and lower WSC content of black oat by harvest of 119 days after planting would inhibit lactic acid yield during silage fermentation, it needed LAB inoculation to become high quality silage. Under adequate DM and the same harvest date, with the longer wilting time, DM of black oat became higher, and the content of WSC fluctuated on different wilting time, but the content of CP and fiber were nearly no difference. With the longer wilting time, the content of lactic acid yield by silage fermentation became lower, but it could be good quality silage without LAB inoculation. Besides, the content of silage lactic acid increased significantly with LAB inoculation, and all of the inoculated silage on different wilting time could attain to excellent quality.

Key words: Oat, Harvest date, Forage quality, Silage.

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