Journal of the Korean Society of Grassland and Forage Science 33(4) : 234~239, 2013
http://dx.doi.org/10.5333/KGFS.2013.33.4.234
ISSN 2287-5824 (Print)
ISSN 2287-5832 (Online)

Effects of Drying Methods on Anthocyanin Contents of Colored Barley (*Hordeum vulgare* L.) cv. Boanchalbori

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ABSTRACT

This study investigated the effects of drying methods and drying time on the changes in anthocyanin content in colored barley. Colored barley cultivar Boanchalbori was harvested at a time when the anthocyanin content was the most and dried in afield. The harvested barley was then treated by two methods, sun drying and shade drying, for 4, 8, 24, and 32 h. The moisture content of the sun-dried barley decreased slightly faster than shade-dried samples, but the difference was not statistically significant. Chemical analysis indicated that the samples dried under shaded conditions had slightly higher crude fiber and lower nitrogen free extract, but the difference was not statistically significant. There was no difference in the total digestible nutrients between the two methods. In the case of sun-dried barley, the anthocyanin content decreased compared to the control and shade-dried samples after drying for 4 h ($p < 0.05$), was maintained at a constant level at 24 h, and then decreased at 32 h. In case of shade-dried barley, the anthocyanin content decreased gradually with the drying time, and a significant decrease was found at 24 h of drying ($p<0.05$) as compared to the control. The shade-dried method was more successful in reducing anthocyanin loss than the sun-dried method ($p<0.05$). There was a slight decrease in 1,1-Diphenyl-2-Picrylhydrazyl radical scavenging with drying time in the shade-dried method, and a significant decrease after 4 h with the sun-dried method. These results showed that covering with a two-layer awning was advantageous to dry colored barley in the field conditions.

(**Key words :** Colored barley, Anthocyanin, Drying method, Drying time)

Ⅰ. INTRODUCTION

Gradually being advanced Korean economy and level of consciousness have been brought high-quality of dietary life and a keen interest in well-being foods, and consumption patterns of livestock products are recently changing from quantity to quality such as well-being functional foods or variety of clean meats. The production of functional meats is congenital quality of livestock but also influenced by the energy source for livestock and feedstuff. Thereby, the development of functional feedstuff for high-quality functional meat production is recently proceeding world-widely (Jang et al., 2010; Cho et al., 2010). One of functional components of plant body, a reddish natural pigment, anthocyanin is widely contained in each of flowers, fruits, stems, leaves, and roots of higher plants, and it is also composed of anthocyanidine and sugar. Anthocyanin, as a kind of naturally existing water-soluble flavonoid pigment, is known to aid anti-cancer, anti-allergy, anti-virus, improvement of immune system (Harborne, 1988; Prior et al., 2005; Kong et al., 2003; Yang et al., 2001; Harbonrne& William, 2000). Therefore, it will be beneficial in production of livestock by reinforcing the immune system of livestock through developing rough feedstuff that contains anthocyanin. Forage barley has been cultivated in Korea by using winter paddy for the production of whole feedstuff which contains seed, leaves, and stems. It is not only to replace general rough feedstuffs but also for partial replacement of feedstuffs for monogastrics (Lee et al., 1994; Park et al., 2008). In Rural Development Administration, Boanchalbori barley, which contains high contents of anthocyanin, was developed recently. It will show high usage as a functional feedstuff. Manifestation mechanism of anthocyanin is extremely complexed, it gets influenced not only by genetic elements but also by numerous environmental factors such as light, temperature, moisture, and nitrogen contents in the body.

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Additionally, anthocyanin content in plant body is also greatly influenced by drying environment and storages after the cultivation. Because drying process is necessary for the use of colored barley as a feedstuff for livestock, this study was accomplished to investigate the change of anthocyanin contents in accordance with drying in the sun and the shade, and drying hours under the certain field condition after the cultivation of colored barley.

Ⅱ. MATERIALS AND METHODS

1. Sample making and analysis

Boanchalbori (*Hordeumvalgare* L.), a colored barley cultivar, used in this study was developed at NICS, RDA, in Korea. The cultivars Boanchalbori were harvested at a time of accumulated anthocyanin more stages (35 to 40 days after heading) and dried in the field conditions. The drying condition was naturally sun-dried and shade-dried (cover with two layers awning dried : transmittancy, 50%), and the drying time was respectively at 4, 8, 24 and 32 hr. After 1kg by taking samples every hour, and dried 72 hours or more circulating drying machine 50°C, weighed, calculating the content of dry matter, were used for analysis by pulverizing it. The crude protein (CP), ether extract (EE), crude ash (CA), nitrogen free extract (NFE), crude fiber (CF), neutral detergent fiber (NDF) and acid detergent fiber (ADF) were measured by the methods of AOAC (2000) and Van Soest et al. (1991). Total digestible nutrients (TDN) was calculated using the formula TDN (%) = 88.9 − (0.79 × %ADF) (Holland, 1990). For the anthocyanin content analysis, the 0.2 g samples were mixed with 2 ml 0.01N HCI-80% Methanol solution and extracted at 4°C in a shaking incubator for 24 hr. The extract which was passed through a 0.2 um syringe filter was determined by high-performance liquid chromatography (HPLC). The HPLC conditions for the analysis of anthocyanins were shown in Table 1.

Table 1. HPLC conditions for the analysis of anthocyanins

Items	Conditions
Column	YMC-Pack ODS-AM
Detector	UV, 520 nm
Flow rate	0.9ml/min
Solvent	A: 5% formic acid B: Acetonitrile + formic acid
Absorbance	520 nm
Injection volume	10 ul

Measurement of antioxidant capacity was carried out using 1,1-Diphenyl-2-Picrylhydrazyl (DPPH) as a free radical. Reduction of DPPH by an antioxidant or a free radical produces decreased absorbance at 515 nm. 100uL of the extract were mixed with 100 uL DPPH (0.4mMol). After 10 min, the plate was reed at 517 nm in a spectrophotometer. The analysis was performed in triplicate.

2. Statistical analysis

The data of this experiment was subjected to SAS Ver. 9.1 program and statistically significant differences among means were determined using Duncan's multiple range test at 5% probability (SAS, 2002).

Ⅲ. RESULTS AND DISCUSSION

1. Agronomic characteristics and Productivity of colored barley

The agronomic characteristics and productivity of colored barley were shown in Table 2. For the agronomic characteristics, plant height and spike length were respectively 86 cm and 3.0 cm and heading date was at April 23. In the productivity, fresh yield was 25 ton/ha, dry matter yield and TDN yield were 12 and 8 ton/ha, respectively.

Table 2. Agronomic characteristics and productivity of colored barley

Cultivar	Heading date	Agronomic characteristics			Forage productivity (Ton/ha)		
		Plant height (cm)	Spike length (cm)	No. of tillers per m^2	Fresh	Dry	TDN yield
Boanchalbori	April 23	86	3.5	689	24.8	11.8	8.3

2. Moisture content

Changes of moisture content according to drying method and time were shown in Fig. 1. In the drying method, moisture content of naturally sun-dried samples was decreased slightly faster than shade-dried samples, but did not show a significantly different, statistically. After drying 8 hrs, the moisture content of sun-dried and shade-dried samples were decreased 42.3% and 43.5% respectively, comparing to 57.1% at harvesting. And, the moisture content was decreased to 35.8% and 37.2% after drying 32 hrs. It is possible to produce a powder sample using a pulverizer for make feed of livestock. Freeze-drying or machine drying is usually used to make dried samples, but those methods are high cost and low practicality. However, drying in the field is suitable method for large quantity of samples. In this study, it is necessary to minimize the loss of anthocyanin content in Boanchalbori, thus it is dried with covering with awning. Using two layers of awning resulted in no significant difference between the natural drying.

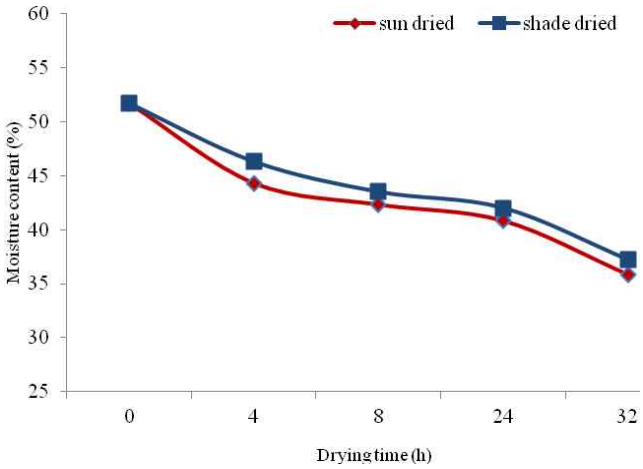

Fig. 1. Changes of moisture content according to drying method and time in colored barley.

3. Chemical compositions

Changes in chemical compositions of colored barely according to drying method and time were shown in Table 3. In the drying time, crude fiber content showed slightly higher than the control sample and nitrogen free extract content was lower compared to the control sample but not significantly different. The other compositions were at similar levels with prolonged drying time and TDN content at the first levels. In the drying method, all components in both the sun and shade dried of samples were similar levels. Fiber as a component of cell walls that form the plant structure is related to intake and digestibility with the role of feel a sense of fullness in livestock. Kim et al. (2006) reported that crude fiber content was increased with prolonged wilting period but other components did not show any trends. The crude fiber content of oat cultivar

Table 3. Changes in chemical compositions according to drying method and time in colored barley

Drying method	Drying Time (h)	Chemical composition (%)							
		CP[1)]	EE	CA	NFE	CF	NDF	ADF	TDN
	0	6.5	1.9	7.1	56.3	21.7	46.9	24.9	69.2
Sun-dried	4	6.4	2.0	6.9	54.7	22.9	46.7	25.0	69.1
	8	6.4	2.1	6.7	54.9	22.9	47.4	25.3	68.9
	24	6.3	2.0	6.8	53.5	23.6	45.1	24.4	69.6
	32	6.3	2.1	6.7	54.1	23.8	46.7	24.8	69.3
	Mean	6.4	2.0	6.8	54.3	23.3	46.5	24.9	69.2
Shade-dried	4	6.4	2.3	6.7	54.7	22.6	46.7	25.2	69.0
	8	6.4	2.2	6.8	55.2	22.4	46.2	24.0	69.9
	24	6.3	2.0	6.8	55.3	22.6	47.6	25.2	69.0
	32	6.2	2.1	6.6	54.3	23.8	47.0	25.0	69.2
	Mean	6.3	2.2	6.7	54.9	22.9	46.9	24.9	69.3

[1)] CP: crude protein, EE: Ether extract, CA: Crude Ash, NFE: Nitrogen Free extract, CF: Crude Fiber, NDF: neutral detergent fiber, ADF: acid detergent fiber, TDN: total digestible nutrients.

was increased as the curing progressed, and the difference of crude fiber content of oat cultivar was maintained through the whole curing period (Han and Kim, 1996). But Gordon (1981) also reported that crude fiber content was not significantly different wilting treatments of herbage. In this study, fiber contents were not changed with prolonged drying period.

4. Anthocyanin content

Changes in anthocyanin content of colored barley according to drying method and time were shown in Fig. 2 and Table 4. In case of sun-dried, cyaniding-3-glucoside (C3G), Perlargonidin-3-glucoside (P3G), delphinidin (Del), and malvidin-3-gluciside (M3G) contents were significantly decreased compared to the control and shade-dried samples at the after drying 4 hrs (<0.05), however they were maintained at the constant levels up to 24 hrs. But a significant decreased was found at 32 hrs of drying ($p<0.05$). Other anthocyanin components were maintained at the first levels. In case of shade-dried, anthocyanin content showed gradually decrease in accordance with the drying time and significantly

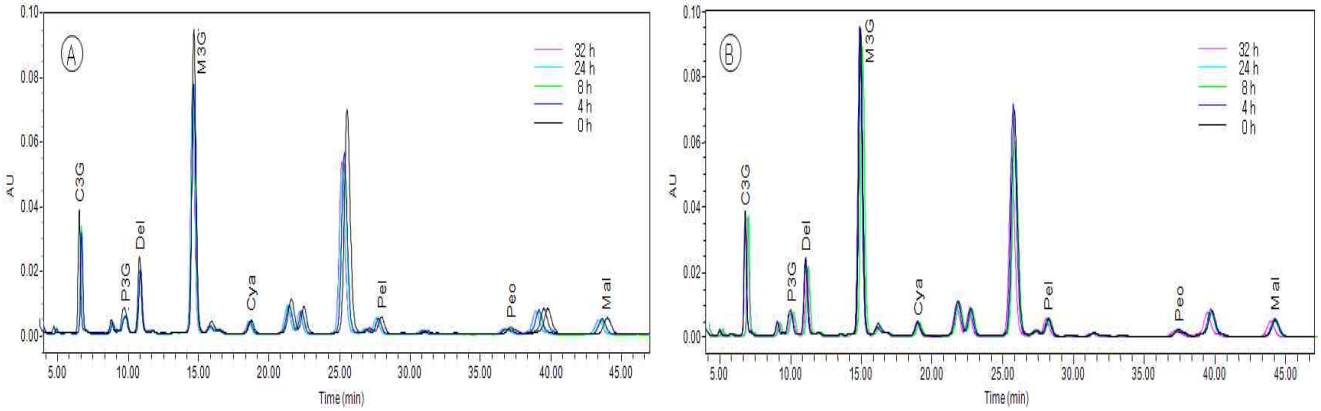

Fig. 2. Anthocyanins of different drying method detected by HPLC.
Ⓐ Sun-dried and Ⓑ Shade-dried

Table 4. Changes in anthocyanin content according to drying method and time in colored barley

Drying method	Drying Time (h)	Anthocyanin content (mg/g)								
		C3G[1)]	P3G	Del	M3G	Cya	Pel	Peo	Mal	Total
	0	0.177^{a}	0.037^{a}	0.116^{a}	0.558^{a}	0.040	0.026	0.024	0.067	1.043^{a}
Sun-dried	4	0.156^{b}	0.028^{c}	0.096^{c}	0.452^{c}	0.035	0.024	0.023	0.062	0.877^{c}
	8	0.152^{b}	0.030^{b}	0.093^{d}	0.449^{c}	0.036	0.025	0.021	0.061	0.866^{c}
	24	0.155^{b}	0.029^{c}	0.092^{d}	0.452^{c}	0.036	0.026	0.021	0.060	0.871^{c}
	32	0.146^{c}	0.028^{c}	0.092^{d}	0.440^{d}	0.035	0.024	0.021	0.061	0.847^{d}
	Mean	0.152^{B}	0.028^{B}	0.093^{B}	0.448^{B}	0.035	0.025	0.022	0.061	0.865^{B}
Shade-dried	4	0.179^{a}	0.032^{ab}	0.117^{a}	0.562^{a}	0.040	0.027	0.022	0.060	1.039^{a}
	8	0.173^{a}	0.035^{a}	0.109^{a}	0.555^{a}	0.037	0.026	0.020	0.061	1.016^{a}
	24	0.170^{a}	0.033^{ab}	0.101^{b}	0.509^{b}	0.037	0.025	0.019	0.060	0.955^{b}
	32	0.170^{a}	0.031^{b}	0.100^{b}	0.493^{b}	0.037	0.027	0.020	0.062	0.938^{b}
	Mean	0.173^{A}	0.033^{A}	0.106^{A}	0.522^{A}	0.038	0.026	0.020	0.063	0.981^{A}

[a-d] Means in the same column with different superscripts are significantly different ($p<0.05$).

[1)] C3G:cyanidin-3-glucoside, P3G:pelargonidin-3-glucoside, Del:delphinidin, M3G:malvidin3-O-glucoside, Cya:cyanidin, Pel:pelargonidin, Peo: peonidin, Mal: malvidin.

decreased as compared to the control after 24 hrs ($p<0.05$). Comparing sun and shade drying methods, shade drying method significantly reduced anthocyanin loss than sun drying method ($p<0.05$). The factors of light, high temperature, oxygen and high pH were associated with anthocyanin stability (Francis, 1989; Mazza and Miniati, 1993). Jenshiroobha et al. (2011) also reported that increasing in pH, temperature and exposure to light is able to spoil the anthocyanin molecule. In this study, sun-dried samples were exposed to sun and shade-dried also has been continued with the impacts of light, because of transmittance to 50% of awning. Because anthocyanin pigments was easily decomposed in the light, in the case of sun-dried and greatly reduced according to drying time but, anthocyanin pigments showed the results of a relatively small reduction in the case of shade-dried.

5. DPPH radical scavenging

Effects of scavenging DPPH Radical by ethanol extract of colored barley according to drying method and time were shown in Fig 3. The DPPH radical scavenging was slightly decreased according to drying time in shade-dried. But in the sun-dried, it was significantly decreased after 4 hrs, thereafter slightly decreased with drying time. Antioxidant activity showed higher when the content of anthocyaninsis high, but antioxidant activity showed lower as the content of anthocyanins was low. Song et al. (2005) reported that antioxidation ability as the content of anthocyanins is high and anthocyanin content has a significant relationship on antioxidant activity. Maritza et al. (2013) reported that the antioxidant activity of strawberries was directly correlated with anthocyanin content in the fruit. In this study, antioxidant activity and anthocyanin content have a positive correlation.

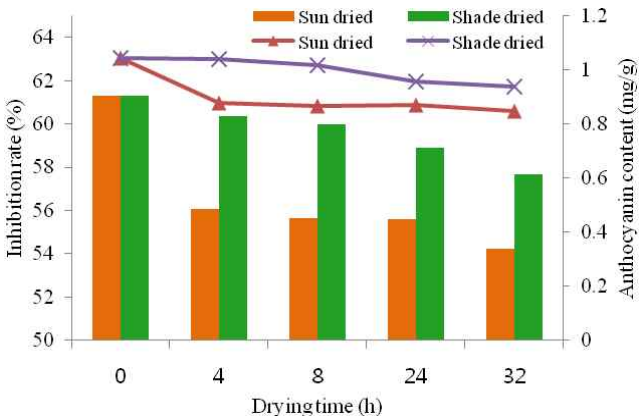

Fig. 3. Scavenging effects of DPPH radical by ethanol extract according to drying method and time in colored barley.
– Bar chart: Inhibition rate (%); line chart: Anthocyanin content (mg/g).

These results showed that if dry in shade without changing chemical compositions can prevent a decrease in anthocyanin content. Therefore, it is advantageous when it's dried and covered with a two-layerawning in the field conditions the colored barley for feedstuff.

Ⅵ. ACKNOWLEDGMENTS

This study was supported by a Postdoctoral Fellowship Program of National Institute of Crop Science (NICS), Rural Development Administration (RDA), Republic of Korea, and a grant from “Cooperative Research Program for Agricultural Science & Technology Development (Project No. PJ007435)”, RDA, Republic of Korea.

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(Received July 10, 2013/Revised November 10, 2013/Accepted November 15, 2013)