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Productive and nutritional aspects of forages oats and barley alone and consociated to vetch in high Andean conditions

Abstract

Forage grasses, such as oats and barley are the most common and cheap source of nutrients for ruminants in the high Andean region. Therefore, information about productivity and chemical composition of these forages are important in the high Andean region. Results indicate that forage oats cultivated at an altitude between 4200 and 4400 meters above sea level produced 30.0 t ha^{-1} of fresh matter (FM) or 5.0 t ha^{-1} of dry matter (DM) and 0.7 t ha^{-1} of crude protein (CP). The crude protein (CP) of oats allows covering the maintenance, pregnancy, or lactation requirements. For the case of barley, the productivity was 35.3 t ha^{-1} of fresh matter (FM) or 9.4 t ha^{-1} of dry matter (DM) and 0.8 t ha^{-1} of crude protein (CP) allowing a milk production of 8 kg cow^{-1} day^{-1}. Regarding associations, the association of oat variety Tayko and vetch in a ratio of 75:25 performed better than other associations, resulting in a production of 58.5 t ha^{-1} of FM or 16.3 t ha^{-1} of DM and 0.76 t ha^{-1} of CP. The association of oat variety Mantaro 15 and vetch in a ratio of 50:50 (7.43% CP) enables milk production of 5.5 kg cow^{-1} day^{-1}. Forage oats and barley are good sources of energy for ruminants due to the neutral detergent fiber concentration (46.70 and 51.76% respectively).

Keywords: oats, vetch, forage, crude protein, energy, ruminants, neutral, detergent

Volume 8 Issue 2 - 2020

Contreras Paco José Luis,[1,2] Ramírez Rivera Hugo,[1] Tunque Quispe Miguel,[2] Aroni Quintanilla Yedy Ruth,[2] Curasma Ccente James[2]

[1]Research members of the FOCAM Project, National University of Huancavelica, Peru

[2]Research members of the Animal Nutrition and Food Evaluation Laboratory, National University of Huancavelica, Peru

Correspondence: Contreras Paco José Luis, Academic Department of Zootechnics, National University of Huancavelica, Ave Agriculture N° 319-321, Sector - Paturpampa, postal code 09001, Perú, Tel +51 948133886, Email jose.contreras@unh.edu.pe

Received: March 30, 2020 | **Published:** June 08, 2020

Introduction

The increasing deterioration of natural resources, together with the increase in human population and their increasing food demand, have led us to think of new forms of sustainable production that allow us to reduce environmental degradation problems.[1] Forage production does not cover the nutritional needs of livestock in quantity and quality, particularly during dry season.[2] Due to the current competitive food production in the agricultural sector, producers are in need to become more efficient in the use of their resources. Therefore, intensify production per unit of area might be one of the actions to become more efficient. However, there is the need to look for forages that satisfy the animal's nutritional requirements, while establishing a uniform harvesting system that ensures a constant production level throughout the year.

There are several external and internal factors that limit the production of forage, being the main one the climate. Thus, under tropical conditions, the forage production is higher in the rainy season than the dry season. This high difference in production during season generates the need for a feed production on a seasonal. Other external factors include the management, physical and chemical conditions, and the ecological characteristics of the land such as high slopes, poor drainage, poor fertility, and low adaptation of the forage species.[3] While the internal factors include type of seed and the physiological stages of the plants. The form of growth of the plant determines their use and how it should be used. The physiological stages determine the amount of non-structural carbohydrates as an energy reserve for growth and leaf area, the interaction between this generates the new growth.[4]

Oat (*Avena sativa* L.) is a grass commonly used as winter forage in the high Andean region, and they are commonly used to feed cattle[5] mainly due to the high concentration of fermentable carbohydrates.[6] Despite their high nutritive composition,[7] local cultivars have not favorable characteristics such as small grain, regular foliage, and high disease susceptibility.[8] However, it is a crop that adapts to different environmental conditions, altitudes, and managements.[9]

The barley (*Hordeum vulgare* L.) is a grass characterized by being vigorous, resistant to drought and salinity, can be grown in marginal soil, and have rapid growth. Consequently, forage and grain productions are produced in the shortest time under a low production cost.

It has been established that the biomass increases from the vegetative stage to the pasty grain, and declines as it approaches to the physiological maturity, while the quality reduces due to the elongation of the stems and changes in the cell wall structure. Good forage for ruminants should have an adequate proportion of leaf-stem. Therefore, the objective of this study is to estimate the productivity and the nutritional composition of cultivars of forage oats and barley alone and intercropped with Vetch in the high Andean region.

Methods

Location, soils and experimental design

The study was carried out within the framework of the project "Evaluation of the sowing of oats and barley associated with vetch and forage conservation techniques to feed alpacas in the high Andean areas in the provinces of Huancavelica, Castrovirreyna and Huaytara in Huancavelica Region, Peru" supported by FOCAM of the National University of Huancavelica, Faculty of Engineering Sciences, Professional School of Animal Husbandry. The experiment was performed from November 2015 to May 2016 with a mean rainfall of 443 mm and a minimum environmental temperature of -0.2°C and a maximum of 12.9°C. (Tunnel Zero Station - Huaracco).

The soil was selected and mechanized prepared before soil analysis. Then, the sowing was done through broadcast sowing. The parameters evaluated were plant height, number of plants per m^2, and number of Stems per plant. Plant height was measured in 5 samples

per experimental unit. The number of plants was measured in 4 samples, each sample had a frame of 0.06 m^2. The number of Stems per plant were measured in 5 samples. The fresh matter yield (FMY) of 4 sub samples of 0.25 m^2 were taken in each experimental unit considering an edge effect of 30 cm.[10]

The monoculture of oats was performed in Rumichaca at 4251 masl (UTM coordinate 498781, 8531085) and Taccsana at 4468 masl (UTM coordinate 501321, 8537319) located in the Indigenous Community of Carhuancho, district of Pilpichaca, province of Huaytara, department of Huancavelica in Peru.[11] The experimental design was a completely randomized design with a factorial arrangement of 2x6 (i. e., two locations x six oats varieties) with 3 replications, and a total of 36 sub plots of 20.25m^2 considering as experimental units.

Six varieties (i. e., Africana, Centenario, Mantaro, Strigosa, Tayko and Vilcanota) of oats were cultivated using broadcast sowing with a plant density of 120 kg ha^{-1} beginning the last week of November 2015 and ending 140 days later.

The soil was classified according to the La Molina National Agrarian University,[12] where Rumichaca was classified as Loam sand with N 0.56%, P 20.9 ppm, K 654ppm, and pH 4.6, while Taccsana was classified as Loam sandy with N 0.82%, P 158.1ppm, K 4180ppm, and pH 6.10.

The monoculture of barley was performed in Paturpampa at 3778 masl (UTM 504389, 8587517) and Tambocucho at 4266 masl (UTM 488591, 8576986) of the Research and Development Center Lachocc for South American camelids located in the district, province, and department of Huancavelica in Peru.

The experimental design was a completely randomized design with a factorial arrangement of 2x3 (i. e., two locations x three barley densities) with 3 replications, and a total of 18 sub plots of 20.25m^2 considering as experimental units.

One variety of barley (i. e. Centenario) was cultivated using broadcast sowing with a plant density of 90, 100, 110 kg ha^{-1}, the harvest was after 130 days.

The soil was classified according to the La Molina National Agrarian University,[12] where Paturpampa was classified as Loam to Loam sand with N 0.21%, P 4.3ppm, K 92ppm, and pH 5.14, while Tambocucho was classified as Loam sandy with N 0.65%, P 44.5ppm, K 858ppm, and pH 4.92.

The association of oat and vetch was performed in Tucumachay at 4452 masl (UTM 489568, 8574277) of the Research and Development Center Lachocc for South American camelids located in the district, province, and department of Huancavelica in Peru.

The experimental design was a completely randomized design with a factorial arrangement of 6x5 (i. e., varieties, proportions) with 3 replications, and a total of 90 sub plots of 20.25m^2 considering as experimental units.

Six varieties of oat (i. e. Africana, Centenario, Mantaro, Strigosa, Tayko y Vilcanota) was cultivated using broadcast sowing with a plant density of 50 kg ha^{-1} for the vetch and 100 kg ha^{-1} for the oats, the harvest was after 150 days. Seeds were sown in rows with a row distance of 25 cm in between. Association of oat and vetch was performed according to the following proportions (%): 0:100, 25:75, 50:50, 75:25, and 100:0.

The soil was classified[12] as Loam sandy with N 0.22%, P 13.7ppm, K 200ppm, and pH 4.61. The samples were analyzed by the Laboratory of Food Nutrition and Evaluation of the National University of Huancavelica (LUNEA). The chemical composition included dry matter (% DM), crude protein (% CP), organic matter (% OM), neutral detergent fiber (% NDF), acid detergent fiber (% ADF) and mineral matter (% MM).[13] Statistical analysis was performed using SAS 9.4 Statistical Program.[14]

Results and discussion

Oats varieties study

No significant differences in plant height of the six varieties (i. e., mean of the six varieties) were found between ($P<0.05$) Rumichaca (4251 masl) and Taccsana (4468 masl). The plant height mean was 83 cm with a standard deviation of±3.67. The plant height depends on the genotype-environment interaction and it is affected by nutritional composition, soil texture, plant health, temperature, humidity, and quantity and quality of sunlight.[15]

The number of plants per m^2 was higher in Rumichaca than in Taccsana, while the number of Stems was higher in Taccsana than Rumichaca (Table 1). The fresh matter production (FM) was similar ($P>0.05$) in both locations with an average production of 30 t ha^{-1}, equivalent to an average production of 5.004 t ha^{-1} of DM. The production of DM (5.004 t ha^{-1}) is less than 10.269 t ha^{-1} of DM reported by Montoya QK, et al.,(2017),[16] who worked at an altitude of 3313 masl (lower than the present study, 4251 masl and 4468 masl) in four varieties of oats (centennial, Mantaro 15, INIA 2000 and INIA Santa Ana), harvesting grass grain in the phenological state, but similar to 6.028 t ha^{-1} of DM found by Contreras JL, et al.,(2019),[17] who worked at altitudes of 3670 masl in oats variety Mantaro 15, allowed better productive parameters in dry forage yields.

Table 1 Means of the variables of six varieties of oats grown at different altitudes (masl)

Variables	Location		Mean
	Rumichaca	Taccsana	
	4251 masl	4468 masl	
Height plant (cm)	85.62 ± 17.76^A	80.43 ± 20.77^A	83.0
N° plants m^{-2}	241.6 ± 59.87^A	90.0 ± 51.85^B	165.8
N° Stems $plant^{-1}$	7.8 ± 2.60^B	13.3 ± 3.94^A	10.5
FM (t ha^{-1})	30.33 ± 9.27^A	29.25 ± 17.77^A	30.00
DM (%)	19.46 ± 4.10^A	13.89 ± 1.83^B	16.68
CP^1	8.84 ± 2.72^B	19.07 ± 1.86^A	13.96
MM^1	7.53 ± 1.89^B	13.79 ± 4.16^A	10.66
OM^1	92.47 ± 1.89^A	86.21 ± 4.16^B	89.34
NDF^1	44.96 ± 4.67^B	48.43 ± 2.22^A	46.7
ADF^1	27.12 ± 3.53^A	27.44 ± 2.05^A	27.28

^{1}=Percentage in dry matter, FM=Fresh matter, DM=Dry matter, CP=Crude protein, MM=Mineral matter, OM=Organic matter, NDF=Neutral detergent fiber, ADF=Acid detergent fiber and masl= meters above sea level. Different letters on the same column differ statistically ($P<0.05$) according to Tukey's test

The varieties of oats with 19.07% of CP obtained in Taccsana were significantly higher ($P<0.05$) than those found in Rumichaca (Graphic 3). Diets with crude protein contents up to 10% satisfy the maintenance requirement of an adult animal.[18] Therefore, the CP value of 8.84% obtained in Rumichaca will cover the maintenance requirements of sheep or alpacas. The 19.07% CP of the oat varieties produced in Taccsana is sufficient for pregnancy or lactation requirements of

the animal.[16] under normal environmental conditions obtained lower contents of CP (6.5 %) of the variety "INIA 901 - Mantaro 15" at the beginning of the pasty grain. however [19] reported similar values of 10.4% and 9.8 % in milky grain stage for Rumichaca, this trend is due to that CP is influenced by the phenological stage, since as its vegetative cycle progresses, the crude protein content decreases.[20]

The neutral detergent fiber content (48.43%) observed at a higher altitude (Taccsana, 4468 masl) was higher in relation to the Rumichaca oats (44.96%). Therefore, these forages with these NDF contents are good sources of energy for animals.[21] Significant differences (P<0.05) were observed in the mineral matter contents, the highest values corresponding to the oats produced in Taccsana (13.79%).

In Table 2, the variables are being studied for each of the varieties of oats. No significant differences (P> 0.05) were observed between varieties for plant height, number of plants m^{-2}, number of Stems $plant^{-1}$, production of FM, nor for DM.

Table 2 Means of the variables of oat varieties from Taccsana and Rumichaca

Variables	Varieties						Mean
	Africana	Centenario	Mantaro 15	Strigosa	Tayko	Vilcanota	
Plant Height (cm))	94.43^{A}	84.07^{A}	76.10^{A}	76.81^{A}	74.36^{A}	92.38^{A}	83.03
N° plants m^{-2}	204.7^{A}	172.7^{A}	160.7^{A}	174.7^{A}	133.3^{A}	148.7^{A}	165.8
N° Stems $plant^{-1}$	11.8^{A}	10.2^{A}	10.5^{A}	11.0^{A}	8.70^{A}	11.0^{A}	10.50
FM (t ha^{-1})	29.80^{A}	34.31^{A}	34.54^{A}	29.78^{A}	18.08^{A}	32.26^{A}	29.80
DM (%)	17.77^{A}	14.93^{A}	17.32^{A}	17.55^{A}	16.72^{A}	15.78^{A}	16.68
CP[1]	14.25^{B}	16.29^{A}	13.54^{B}	11.79^{C}	14.33^{B}	13.54^{B}	13.96
MM[1]	10.05^{A}	10.99^{A}	13.08^{A}	9.53^{A}	12.01^{A}	8.31^{A}	10.66
OM[1]	89.95^{A}	89.01^{A}	86.92^{A}	90.47^{A}	87.99^{A}	91.70^{A}	89.34
NDF[1]	46.33 ^{BC}	48.31^{AB}	44.83^{C}	43.82^{C}	46.80^{BC}	50.09^{A}	46.70
ADF[1]	28.19^{AB}	27.64^{AB}	26.96^{AB}	25.77^{AB}	25.51^{B}	29.62^{A}	27.28

[1]:=Percentage in dry matter, FM=Fresh matter, DM=Dry matter, CP=Crude protein, MM=Mineral matter, OM=Organic matter, NDF=Neutral detergent fiber and ADF=Acid detergent fiber. Different letters on the same column differ statistically (P <0.05) according to Tukey's test

The oat variety Centenario with 16.29% of crude protein had the highest crude protein compared with the other varieties, while varieties "Africana", "Mantaro 15", "Tayko" and "Vilcanota" showed similar values of crude protein. The variety "Strigosa" had the lowest value. In general terms, the varieties of oats under study will cover the pregnancy and lactation requirements of the animals.[18]

For a good quality forage species, a dry matter consumption of 2.5% of the animal body weight is required.[22] A 500kg body weight cow will have a daily dry matter intake of 12.50kg of DM (500x0.025). Considering an average crude protein value of 13.96% (Table 2), the dry matter intake of crude protein will be 1.745kg, covering the maintenance requirements of the cow (0.432kg of CP,[23] and making available 1.313kg of CP (1.745–0.432). Theoretically this cow milk will produce 15kg cow-1 day-1 (1,313 / 0.090), considering that to produce 1kg of milk, 0.090kg of CP is required. No differences in NDF content were observed between Centenario and Vilcanota variety (NDF=49.20%), while in the other varieties the NDF contents ranged from 43.82 to 46.80%. The NDF content observed in this study were lower than reports of other authors,[16] who obtained a NDF content of 73.77% in pasty grain of the variety Centenario.

A similarity (P>0.05) was observed in the behavior in most of the parameters studied between oat varieties, with difference (P<0.05) from the Vilcanota variety in the NDF and ADF (Figure 1). The intake of these oat varieties will allow the growth of young sheep and alpacas. In addition, these oat varieties will promote good reproductive rates and milk production.

Study of barley as forage

The plant density did not influence plant height, despite the high range observed between the extreme values of 98 and 107 cm for the planting density of 90 and 100kg of barley, respectively. Same pattern was observed on the number of stems per plant (10 Stems $plant^{-1}$).

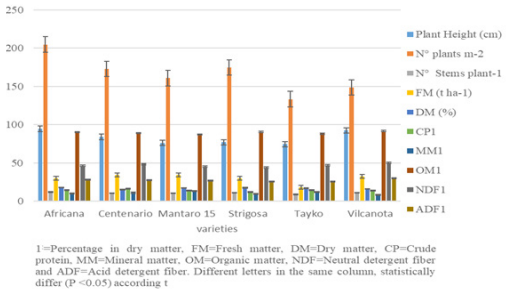

Figure 1 Means of the variables of varieties of oats (Taccsana and Rumichaca).

The planting of barley density of 100 kg ha^{-1} compared with the planting density of 90 kg ha^{-1} presented a higher number of plants per m^2. However, no differences in plants per m^2 were observed between planting density 100 and 110 kg ha^{-1}, and planting density 110 and 90 kg ha^{-1}.

The planting density did not influence the FM production (t ha^{-1}) and the DM content (%). The mean production was 35.30 t ha^{-1} of FM, equivalent to 9.36 t ha^{-1} of DM and 0.755 t ha^{-1} of CP. Dry matter yields of barley (3.9 t ha^{-1}) was previously shown to be lower than triticale (5.3 t ha^{-1}) and oats (4.1 t ha^{-1}) harvested at a phenological state of dough grain.[24] However, barley has a higher forage quality than oats and triticale harvested at the same stage of maturity,[25,26] obtained a higher value of CP (10.4%) of the Xena variety with a planting density of 55.6 kg ha^{-1} harvested in 2015 and located at 500 m altitude in Saskatchewan University (Saskatoon, SK, Canada).

The planting density of 100 kg ha^{-1} obtained the higher CP content (10.04%) compared to those obtained with 90 and 110 kg ha^{-1} (6.40 vs. 7.76%). These results are lower than the values obtained previously[18] with critical value of 8.5%.[18] under this critical value, DM intake will affect the proper functioning of the rumen. The CP content of 10% obtained with the planting density of 100 kg ha^{-1} would satisfy the maintenance requirements of an adult sheep or alpaca (Table 3).

Table 3 Mean of the parameters evaluated in the barley classified by planting density

Variables	Planting density (kg ha^{-1})			Mean
	90	100	110	
Plant height (cm)	98.00 ± 14.81^{A}	107.00 ± 8.83^{A}	102.61 ± 14.72^{A}	103.00
N° plants m^{-2}	84.7 ± 41.37^{B}	114.0 ± 51.27^{A}	91.3 ± 31.23^{AB}	96.7
N° Stems plant^{-1}	9.70 ± 1.71^{A}	10.10 ± 3.89^{A}	9.00 ± 3.12^{A}	10.00
FM (t ha^{-1})	25.50 ± 5.41^{A}	47.67 ± 33.84^{A}	32.70 ± 26.72^{A}	35.30
DM (%)	27.59 ± 10.92^{A}	25.89 ± 13.41^{A}	26.09 ± 12.12^{A}	26.52
CP^{1}	6.40 ± 3.52^{B}	10.04 ± 7.60^{A}	7.76 ± 5.69^{B}	8.07
MM^{1}	6.57 ± 2.76^{B}	7.97 ± 4.50^{A}	7.89 ± 4.00^{A}	7.48
OM^{1}	93.43 ± 2.75^{A}	92.04 ± 4.49^{B}	92.11 ± 4.00^{B}	92.53
NDF^{1}	49.66 ± 2.17^{B}	52.59 ± 2.61^{A}	53.04 ± 2.49^{A}	51.76
ADF^{1}	29.59 ± 0.37^{B}	35.29 ± 3.49^{A}	37.15 ± 3.75^{A}	34.01

^{1}=Percentage in dry matter, FM=Fresh matter, DM=Dry matter, CP=Crude protein, MM=Mineral matter, OM=Organic matter, NDF=Neutral detergent fiber and ADF=Acid detergent fiber. Different letters on the same column differ statistically (P <0.05) according to Tukey's test

Good quality forage has a dry matter intake (DMI) of 2.5% of the live weight of the animal.[22] Thus, a cow with a body weight of 600 kg will have a DM intake of 15kg (600x0.025) and CP intake of 1.2kg (15x0.0807). The CP intake estimated will cover the CP maintenance requirements (0.406kg)[23] and the remaining CP (0.794kg) can be used for milk production. To produce 1kg of milk, 0.090kg of protein is required. Therefore, theoretically the production of 8kg of milk per day (0.794/0.094) using barley would be possible.

No differences (P>0.05) were observed in NDF between barley with a plant density of 100 and 110 kg ha^{-1}. However, NDF content of barley with a plant density of 100 and 110 kg ha^{-1} were higher than the barley with plant density of 90 kg ha^{-1}. The results of NDF content obtained in this study were in range with values reported previously.[21] Therefore, feeding barley to the animals will allow a moderate growth of young animals (sheep or alpacas). Furthermore, in the case of females, reproductive rates and milk production would not be affected.

The planting density (100 kg ha^{-1}) had a better presentation, with a small inferiority (P>0.05) in the OM, in comparison with the other densities (Figure 2)

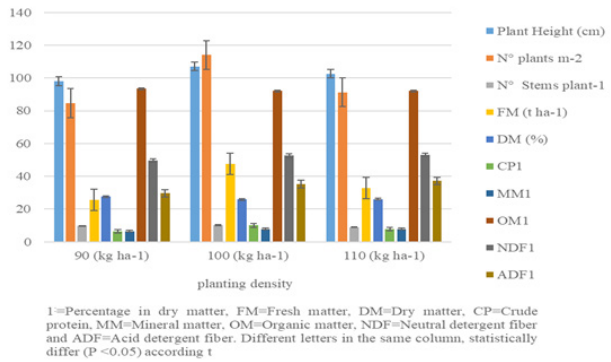

Figure 2 Variable means of barley, according to planting densities.

The plant height in barley was higher in Paturpampa (3778 masl) than in Tambocucho (4266 masl) (Table 4). Planting density of 110 kg ha^{-1} of seeds of barley has been proposed,[27] however such density does not improve grain yield. An increase in plant height was reported when planting density increases from 85 to 160kg ha^{-1}.

Number of plants per m^{2}, stems per plant, and fresh matter production were higher en Tambocucho than in Paturpampa. The CP content of 13.08% observed in barley from Tambocucho was significantly (P<0.05) higher than in Paturpampa. The protein content of 13.08% of the barley will allow a milk production of 15kg per cow per day, similar with the estimates for oats.

The NDF of barley cultivated in Paturbampa was lower than barley cultivated in Tambocucho (50.77 vs. 52.75% of FDN) (Figure 3). Therefore, feeding barley to the animals will allow a moderate growth of young animals (sheep or alpacas) and an adequate milk production due to NDF content ranges between 45-55%, as reported previously.[21]

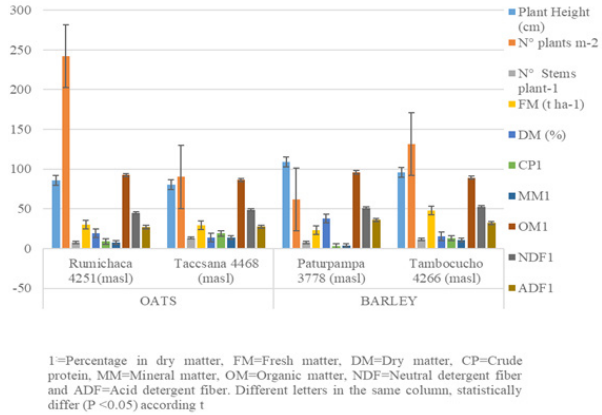

Figure 3 Variable means of oats and barley grown at different altitudes (masl).

Table 4 Mean of the parameters evaluated in the barley classified by altitude (masl)

Variables	Location		Mean
	Paturpampa 3778 (masl)	Tambocucho 4266 (masl)	
Plant height (cm)	108.75 ±5.16^{A}	95.78 ±15.16^{B}	102.26
N° plants m^{-2}	61.8 ±20.70^{B}	131.6 ±22.58^{A}	96.7
N° Stems plant^{-1}	7.8 ±2.84^{B}	11.4 ±1.51^{A}	9.6
FM (t ha^{-1})	22.91 ±5.79^{B}	47.68 ±31.52^{A}	35.30
DM (%)	37.48 ±1.39^{A}	15.56 ±2.79^{B}	26.52
CP^{1}	3.05 ±0.30^{B}	13.08 ±3.54^{A}	8.07
MM^{1}	4.07 ±0.35^{B}	10.88 ±1.44^{A}	7.48
OM^{1}	95.93 ±0.35^{A}	89.12 ±1.44^{B}	92.53
NDF^{1}	50.77 ±3.33^{B}	52.75 ±1.69^{A}	51.76
ADF^{1}	35.89 ±5.14^{A}	32.12 ±2.32^{B}	34.01

^{1}:=Percentage in dry matter, FM=Fresh matter, DM=Dry matter, CP=Crude protein, MM=Mineral matter, OM=Organic matter, NDF=Neutral detergent fiber, ADF=Acid detergent fiber and masl= meters above sea level. Different letters on the same column differ statistically (P <0.05) according to Tukey's test

Study of the association Avena-Vetch

Fresh matter yield was similar in Tayko, Mantaro 15, Vilcanota, Strigosa and Africana varieties associated with different proportions of vetch (mean 33 t ha^{-1}) (Table 5). The lowest fresh matter yield was found in the Centenario variety. The means of the oat-vetch proportions did not show significant differences (P>0.05) in the yield of fresh matter. Numerically the 75:25 ratio showed the highest yields, followed by the 50:50 ratio and finally by the 25:75 ratio (oats-vetch).

Table 5 Fresh matter yield (t ha^{-1}) of different proportions of oat-vetch in Tucumachay-Huancavelica

Fresh matter yield (t ha^{-1})								
Proportion (%)		Tayko	Mantaro 15	Centenario	Vilcanota	Strigosa	Africana	Mean
Oats	Vetch							
0	100	2.40	2.40	2.93	3.07	2.47	5.00	3.04^{b}
25	75	43.13	33.80	36.47	36.53	32.80	27.73	35.08^{a}
50	50	45.67	32.87	32.93	43.60	59.40	28.67	40.52^{a}
75	25	58.47	39.47	30.20	43.47	39.53	49.00	43.36^{a}
100	0	45.40	42.93	27.67	33.53	37.53	38.00	37.51^{a}
Mean		39.01^{A}	30.29^{AB}	26.04^{B}	32.04^{AB}	34.35^{AB}	29.68^{AB}	31.90

Different letters on the same column differ statistically (P <0.05) according to Tukey's test

The highest fresh matter yield was found in the association of oat variety Tayko with vetch in a proportion of 75:25. Similarly, the 75:25 ratio (oat variety African-vetch) allowed higher productions of fresh matter (49 t ha^{-1}) compared to the other proportions of the African-vetch variety.

Significant differences (P<0.05) were found in fresh matter production between the five proportions of oats-vetch. The extreme values of 32.17 and 40.03% correspond to the proportions of oats-vetch of 100:0 and 0:100, respectively (Table 6). Considering that NDF represents the highest proportion of dry matter in feeds, it could be inferred that the oat-vetch ratio (0:100) was the most fibrous than the other proportions.

In general, the dry matter contents between the varieties did not show significant differences (P>0.05), despite the wide range observed between the extreme values of 30.93 to 36.94% for the Tayko and African variety, respectively.

The ratio oats-vetch of 0:100 with Strigosa-vetch showed a higher DM content (48.12%) compared with Mantaro 15-vetch (45.78%) and African-vetch (42.25%). The Vilcanota-vetch variety had the lowest dry matter content (31. matter 67%) and other proportions provided intermediate values of DM. The participation of the Vilcanota-vetch variety (100:0) numerically showed the higher DM content (37.52%) in relation to the other oat-vetch varieties.

No statistical differences (P>0.05) were found in CP concentration between varieties. However, the sowing oat: vetch ratio showed higher protein concentrations in pure vetch (27.84%) and lower concentrations in oat monocultures (4.80%). There were no significant differences (P> 0.05) in the CP between the proportions 25:75, 50:50, 75:25 and 100:0 of oats-vetch, a decrease of CP being verified as the proportion of vetch increases (Table 7).

The 25:75 ratio (Vilcanota-Velch oats) had a CP value of 23.81%. A cow of 500kg of BW would consume 12.50kg of DM (500 x 2.5%, good quality forage) daily, equivalent to 2.976kg of CP. After meeting the maintenance requirements (0.432kg), there would be the theoretical possibility of producing 28kg milk. This same animal fed equal parts of Mantaro 15-vetch oats (7.43% of CP) would produce 5.5kg day^{-1} of milk.

The experimental plots with only vetch have a mineral matter significantly high (P<0.05) (16.79%) compared to the other proportions of oat-vetch, which did not differ from each other, with mean of 6.21% (Table 8). Numerically, differences were observed in mineral matter between the varieties of oat-vetch with a proportion of 50:50, 75:25 and 100:0.

Table 6 Average dry matter content (%) of the oat-vetch associations in different proportions in Tucumachay-Huancavelica

Dry matter (%)								
Proportion (%)		Tayko	Mantaro 15	Centenario	Vilcanota	Strigosa	Africana	Mean
oat	vetch							
0	100	37.30	45.78	35.04	31.67	48.12	42.25	40.03[a]
25	75	29.90	32.38	31.78	36.04	35.50	36.31	33.65[ab]
50	50	30.92	28.04	31.54	31.56	26.69	37.02	30.96[b]
75	25	27.82	31.33	32.34	35.92	35.70	34.09	32.87[ab]
100	0	28.71	26.89	32.64	37.52	32.22	35.04	32.17[b]
Mean		30.93[A]	32.89[A]	32.67[A]	34.54[A]	35.65[A]	36.94[A]	33.94

Different letters on the same column differ statistically (P <0.05) according to Tukey's test

Table 7 Average crude protein contents (%) of oat-vetch associations in different proportions in Tucumachay-Huancavelica

Proportion (%)		Crude protein (%)						
oat	vetch	Tayko	Mantaro 15	Centenario	Vilcanota	Strigosa	Africana	Mean
0	100	24.41	24.99	31.33	33.71	25.94	26.67	27.84[a]
25	75	6.67	6.77	6.43	23.81	6.82	3.95	9.08[b]
50	50	4.38	7.43	4.90	5.92	4.85	4.78	5.38[b]
75	25	4.70	5.44	5.13	5.20	4.35	4.42	4.88[b]
100	0	4.21	7.04	4.78	5.03	3.87	3.83	4.80[b]
Mean		8.87[A]	10.34[A]	10.52[A]	14.74[A]	9.17[A]	8.73[A]	10.39

Different letters on the same column differ statistically (P <0.05) according to Tukey's test.

Table 8 Average contents of mineral matter (%) of the oat-vetch association with different proportions in Tucumachay-Huancavelica

		Mineral matter (%)						
Proportion (%)		Tayko	Mantaro 15	Centenario	Vilcanota	Strigosa	Africana	Mean
Oat	Vetch							
0	100	6.92	6.62	23.10	14.66	15.96	14.68	16.79[a]
25	75	6.18			8.98	6.63	5.29	6.77[b]
50	50	5.23	9.30	5.58	6.56	5.80	5.70	6.36[b]
75	25	5.52	6.13	6.72	5.63	6.13	5.61	5.96[b]
100	0	5.53	7.03	5.53	5.08	6.05	5.44	5.78[b]
Mean		8.12[A]	8.72[A]	9.51[A]	8.18[A]	8.12[A]	7.35[A]	8.33

Different letters on the same column differ statistically (P <0.05) according to Tukey's test

Conclusion

a. Barley and oats are crops that can be as an alternative to mitigate the low quality forage found during dry seasons in the highland areas of the Peruvian highlands.

b. The barley cultivated in the Puna region showed a good yield in CP (10.04%) at a planting density of 100kg ha^{-1} with a fresh matter production of 47.67 t ha^{-1}.

c. The Tayko-Vetch oats association (75:25) stood out, with high production of fresh matter (58.47 tha^{-1}), dry matter (16.27 tha^{-1}) and crude protein (0.764 tha^{-1}), compared with the other associations.

d. The association of equal parts (50:50) of Mantaro15 oats (7.43% CP) – vetch enables a milk production of 5.5 kg cow^{-1} day^{-1}. Due to the neutral detergent fiber concentrations (46.70 and 51.76%), oats and barley used as forage resources represent good sources of energy for ruminants.

Citation: Luis CPJ, Hugo RR, Miguel TQ, et al. Productive and nutritional aspects of forages oats and barley alone and consociated to vetch in high Andean conditions. *MOJ Food Process Technol.* 2020;8(2):59–65. DOI: 10.15406/mojfpt.2020.08.00243

Funding

This research project was sponsored by the FOCAM funds of the Project "Evaluation of the sowing of oats and barley associated with vetch and to conserve forage for feeding alpacas in the high Andean areas in the Huancavelica district, the provinces of Huancavelica, Castrovirreyna and Huaytara de la Huancavelica region" of the National University of Huancavelica, for the support provided in carrying out this research.

Acknowledgments

Thanks to the FOCAM funds of the Project " Evaluation of the sowing of oats and barley associated with the vetch and conservation of the forage for feeding alpacas in the high Andean areas in the Huancavelica district, Huancavelica, Castrovirreyna and Huaytara provinces of the region Huancavelica of the National University of Huancavelica, for the support provided in carrying out this Research.

Conflicts of interest

The authors declare that there was no conflict of interest.

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