Influence of varying levels of dried citrus pulp on nutrient intake, growth performance and economic efficiency in lambs

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ABSTRACT
The study was conducted to evaluate the influence of partial replacement of concentrate with dried citrus pulp (DCP) on nutrient intake, digestibility, nitrogen metabolism, growth rate and economic efficiency in lambs. Citrus pulp was sun dried and chemical evaluation was conducted. Forty entire male \textit{Lohi} lambs approximately 4–5 months of age were used in a randomized complete block design. On the basis of body weight, lambs were divided into 4 groups, 10 lambs in each group. The animals were fed 30% forages and 70% concentrate. The concentrate contained DCP10%, DCP20%, DCP30% or DCP40%. The experiment continued up to 120 days. A non-significant effect was observed on nutrient intake and digestibility by various levels of DCP. Nitrogen balance was also remained unaffected among the treatments. A non-significant effect was observed on average daily gain in lambs fed varying levels of DCP. A decreasing trend in price per kg of feed was observed as the level of DCP increased in the diet. These results indicated that DCP can be used successfully up to 40% of the concentrate in the diet of lambs without any adverse effect on feed intake and growth performance.

Introduction

A tremendous increase in the population of the world has elevated the demand of grains, consequently increasing the competition between humans and animals for grains and other food sources, which has resulted in higher prices of concentrate. Most of the livestock farmers are unable to feed concentrate to their animals to fulfil their requirement, which is adversely affecting performance of the animals. In this situation, there is demand for exploring cheaper non-conventional feed resources that can replace concentrate sources, especially grains.

Different agro-industrial by-products especially fruit wastes can be used as an energy source for feeding livestock (Crickenberger 1991). Citrus pulp is an important by-product obtained after extraction of juice from the citrus fruit. A large quantity of pulp is being produced in Pakistan, which is not commonly fed to animals. It causes disposal problems as well as environmental pollution (Ralphs et al. 1995; Intrigliolo et al. 2001). Citrus pulp consists of peels, inside residue and culled fruits (Mirzaei-Aghsaghali & Maheri-Sis 2008). It can be used as an energy source to support growth performance in ruminants (Bampidis & Robinson 2006). Fresh whole citrus pulp is 49.2–69.2% of the fresh citrus fruit (Pascual & Carmona 1980). According to NRC (1996), it contains about 82% total digestible nutrients and 6.7% crude protein (CP). Due to high transportation cost, perishability and seasonal availability, the use of citrus pulp on fresh basis is limited. It can be conserved by drying (dehydration) or ensiling (Bueno et al. 2002). However, handling and transportation of dried citrus pulp (DCP) is easy when compared to ensiled form (Arthington et al. 2002).

DCP has a high nutritive value. It is a concentrate source (Arthington et al. 2002) which contains 120–400 g sugar and less than 10 g starch per kg of dry matter (DM) (Hall 2000). It also contains 25% DM pectin contents, which are approximately 98% digestible (Arthington et al. 2002). Ruminal bacteria can easily degrade the pectin content of DCP (Sunvold et al. 1995). It can be used as an energy source to replace grains (Al Khawajah 2003; Barrios-Urdaneta et al. 2003; Caparra et al. 2007; Gado et al. 2009). Feeding of DCP improves nutrient digestibility in ewes (Fegeros et al. 1995), better growth performance and feed intake in growing kids (Bueno et al. 2002) enhances body weight gain in calves (Schalch et al. 2001) or improves feed intake and economic efficiency in lambs (Caparra et al. 2007).

Limited literature is available regarding the use of DCP as an energy source in ruminant animals of Pakistan. Therefore, the present study was planned to evaluate the effects of DCP as an alternate energy source on feed intake, growth performance, digestibility, nitrogen balance, feed efficiency and economics of feeding in lambs.

Materials and methods

Citrus pulp was collected from a juice extraction company. Just after collection, it was spread on polythene sheets for sun drying. Polythene sheets were used to prevent the soil contamination. After drying, samples were taken and analysed for DM, organic matter (OM) and nitrogen (AOAC 1990), neutral detergent fibre (NDF) and acid detergent fibre (ADF) (Van Soest et al. 1991).
The study was arranged with the collaboration of Livestock Production Research Institute (LPRI), Bahadarnagar, Okara, Pakistan. Forty entire male Lohi lambs with 4–5 months of age were selected from Livestock Experiment Station, Bahadarnagar, Okara and then shifted to Animal Nutrition Section, LPRI Bahadarnagar, Okara. The protocol for the animal research was approved by the ethics committee of the institute. All the lambs were weighed at day zero (first day after shifting) before morning feeding and thereafter every 15 days before the morning feeding. On the basis of body weight, these animals were randomly distributed into 4 blocks, 10 animals in each, in a randomized complete block design. Lambs were dewormed against endo and ectoparasites before the start of the experiment.

The lambs were fed concentrate and forages in a ratio 70:30. The concentrate contained DCP 10%, DCP 20%, DCP 30% or DCP 40% (Table 1). These diets were fed to lambs. The study continued up to four months. Lambs were given an adaptation period of 21 days to introduce feed, environment, housing and grouping while remaining time for collection period. Animals were fed ad libitum twice daily at 07:00 and 21:00 h.

During the collection period, digestibility of DM, CP, NDF and ADF was determined using total collection method. Three animals from each group were randomly selected and housed in separate metabolic pens individually. Each metabolic pen was made up of iron rods and pipes having $3.5 \times 4.5$ ft² area. Fresh water availability was ensured round the clock. Feed and orts were recorded daily. Total faeces and urine collection was done to determine digestibility and nitrogen balance according to the procedure described by Nisa et al. (2006). Faecal samples were weighed, mixed thoroughly and dried at 55°C. At the end of each collection period, dried faecal samples were composited and 10% of these were taken for analysis (Sarwar et al. 2006). Samples of feed and faeces were taken and ground to pass through a 2-mm screen and analysed for DM and CP (AOAC 1990), while NDF and ADF were analysed using method described by Van Soest et al. (1991).

During last day of each collection, blood samples were taken. Three lambs were selected randomly from each group. Ten millilitre of blood was collected from jugular vein by using syringe and transferred to vacutainer. Serum was extracted by centrifuging at 3500 rpm. It was stored in a deep freezer for further analysis. The blood urea nitrogen was observed through the method described by Bull et al. (1991). Blood glucose was determined by using crescent diagnostic glucose enzymatic colorimetric god-pap method (Trinder 1969), also reported by Sharif et al. (2014). Feed efficiency was calculated by dividing weight gain over feed intake. Cost incurred on each diet was also calculated to determine the economics of feeding.

### Statistical analysis

The data collected for each parameter was subjected to analysis using general linear model procedure of Statistical Package for the Social Sciences (SPSS 1999) and means were compared by Duncan’s Multiple Range Test (Steel et al. 1997).

### Results

Analysis of DCP was carried out to evaluate the relative contents of DM, OM, CP, NDF, ADF and ash, which are good indicators for the determination of nutritive value. The results revealed that DCP contained 90.50%, 94.46% and 6.49% of DM, OM and CP, respectively, while metabolizable energy content was 3056 kcal/kg DM. The NDF, ADF and ash contents of DCP were 20.59%, 14.29% and 5.43%, respectively (Table 2).

Nutrient intake was similar ($P > 0.5$) among different diets (Table 3). A non-significant effect was observed on nutrient digestibility in lambs receiving various levels of DCP (Table 3).

Nitrogen intake, faecal and urinary nitrogen, and nitrogen balance were not different among diets (Table 4). Blood metabolites were similar in lambs fed different levels of DCP (Table 5).

Similarly, growth performance was not affected by inclusion of DCP at various levels in lambs diets (Table 6).

Feed efficiency was remained unaffected by dietary treatments. However, reduction in price per kg feed and price per kg of body weight was observed at higher DCP levels than LDCP diet (Table 6).

### Discussion

Chemical composition of DCP in this study indicates that it is an excellent ingredient for ruminants. Similar CP (6.40%) while higher NDF and ADF (26.21% and 20.35%, respectively) contents were reported by Ibrahim et al. (2011) when compared to our study. However, Fegeros et al. (1995) observed that DCP contained 7.75% CP, 19.4% NDF and 12.8% ADF. The

### Table 1. Ingredients and chemical composition of the experimental concentrate diets for lambs.

| Ingredient            | DCP10 | DCP20 | DCP30 | DCP40 |
|-----------------------|-------|-------|-------|-------|
| DCP                   | 10    | 20    | 30    | 40    |
| Maize broken          | 14    | 10    | 5     | 3     |
| Wheat bran            | 10    | 10    | 7     | 1     |
| Rice polishing        | 17    | 13    | 10    | 5     |
| Sunflower meal        | 10    | 10    | 11    | 13    |
| Canola meal           | 12    | 13    | 14    | 16    |
| Cotton seed cake      | 12    | 12    | 12    | 11    |
| Molasses              | 13    | 10    | 9     | 9     |
| Mineral mix           | 2     | 2     | 2     | 2     |
| Total                 | 100   | 100   | 100   | 100   |

| Chemical composition (%) | DM     | CP       | Metabolizable energy (Mcal/kg) | NDF   | ADF |
|--------------------------|--------|----------|--------------------------------|-------|-----|
|                         | 88.6   | 16.1     | 2.7                            | 27.3  | 13.58 |
|                          | 89.23  | 16.15    | 2.72                           | 28.27 | 14.73 |
|                          | 89.66  | 16.10    | 2.71                           | 28.63 | 15.86 |
|                          | 89.94  | 16.10    | 2.71                           | 27.54 | 16.67 |

*DCP10, DCP20, DCP30 and DCP40 represent low DCP, medium DCP, high DCP and very high DCP, respectively.

| Item       | DCP (%) |
|------------|---------|
| DM         | 90.50   |
| OM         | 94.46   |
| CP         | 6.49    |
| Metabolizable energy (Mcal/kg) | 3056 kcal/kg |
| NDF        | 20.59   |
| ADF        | 14.29   |
| Ash        | 5.43    |

Table 2. Chemical composition of DCP.
variation in nutrient composition of DCP might be attributed to different seed contents of the citrus fruit as their number varies from 0% to 10% (Jong-Kyu et al. 1996).

No effect on nutrient intake was observed in lambs fed diets having different levels of DCP. Our findings were consistent with McCullough and Sisk (1972), who found lack of effect on nutrient intake in steers fed different levels (15% and 25%) of DCP. Taniguchi et al. (1999) also reported that feed intake remained unaltered by feeding diets containing various levels of DCP. This might be due to the fact that DCP has same energy values as grains when fed in diets of ruminants due to which no results on nutrient intake were observed (Ahoeei et al. 2011). On the other hand, Highfill et al. (1987) stated that nutrient intake was higher in cows fed total mixed ration (TMR) having DCP than those fed TMR having soya hulls and corn gluten feed. Rams fed diet having DCP showed better nutrient intake than those fed diet having barley grains (Ben-Ghedalia et al. 1989). The improved feed intake might be attributed to more likeness or palatability of DCP (Oni et al. 2008).

Lack of effect on nutrient digestibility was observed in lambs receiving various levels of DCP. It was found that substitution of barley with citrus pulp had non-significant effect on DM digestibility (Castrillo et al. 2004). Abdullah and Sharif (2014) also reported non-significant effects of DCP on DM digestibility. Contrary to these findings, Sudweeks (1977) stated that digestibility increased with increasing the levels of DCP in the diets of sheep. Nutrient digestibility was higher in cows fed DCP-based TMR when compared to soya-hulls- and corn-gluten-feed-based TMR (Highfill et al. 1987). This might be due to total soluble solids and neutral detergent soluble carbohydrates like pectins present in DCP that would be rapidly digested in the rumen (Nam et al. 2009).

### Table 3. Effects of varying levels of DCP on nutrient intake in lambs.

| Parameters      | DCP10 | DCP20 | DCP30 | DCP40 | SEM  |
|-----------------|-------|-------|-------|-------|------|
| Intake (kg/day) | 1.35  | 1.37  | 1.39  | 1.41  | 0.026|
| Digestibility (%) | 69.53 | 69.13 | 68.13 | 67.79 | 1.103|
| Intake (kg/day) | 1.23  | 1.24  | 1.26  | 1.28  | 0.061|
| Digestibility (%) | 71.61 | 71.28 | 70.50 | 70.42 | 0.987|
| Intake (kg/day) | 0.20  | 0.20  | 0.21  | 0.21  | 0.010|
| Digestibility (%) | 71.44 | 70.63 | 70.30 | 69.22 | 1.076|
| Intake (kg/day) | 0.29  | 0.29  | 0.31  | 0.31  | 0.010|
| Digestibility (%) | 50.09 | 49.52 | 48.81 | 47.14 | 1.959|
| Intake (kg/day) | 0.23  | 0.24  | 0.25  | 0.25  | 0.008|
| Digestibility (%) | 47.18 | 46.99 | 46.47 | 46.10 | 2.148|

Note: DCP10, DCP20, DCP30 and DCP40 represent low DCP, medium DCP, high DCP and very high DCP, respectively. SEM indicates standard error mean.

### Table 4. Effects of varying levels of DCP on nitrogen balance in lambs.

| Nitrogen(%) | DCP10 | DCP20 | DCP30 | DCP40 | SEM  |
|-------------|-------|-------|-------|-------|------|
| Intake      | 31.99 | 32.16 | 33.25 | 33.76 | 0.637|
| Faeces      | 9.26  | 9.61  | 9.93  | 10.38 | 0.430|
| Urine       | 13.68 | 13.90 | 14.02 | 13.70 | 0.820|
| Nitrogen balance | 9.06  | 8.65  | 9.30  | 9.68  | 0.914|

Note: DCP10, DCP20, DCP30 and DCP40 represent low DCP, medium DCP, high DCP and very high DCP, respectively. SEM indicates standard error mean.

Our findings were supported by Bueno et al. (2002) and Javed et al. (2016), who observed no effect of DCP on nitrogen balance in Saanen kids. It remained unaltered by feeding various levels of DCP in Awassi lambs (Bhattacharya & Harb 1973). The probable reason for this might be attributed to similar chemical composition of diets.

Feeding varying levels of DCP had no effect on blood metabolites. Blood urea nitrogen was remained unaffected in fattening male calves fed DCP-based diets (Ahoeei et al. 2011). Our findings were in accordance with Broderick et al. (2002), who reported that blood glucose remained unaltered in cows fed DCP-based diets. Lack of effect of DCP on blood glucose might be attributed to non-significant intake and digestibility of DCP-based diets.

Caparra et al. (2007) also reported non-significant effect of DCP on live body weight in lambs. Feeding DCP-based diets did not affect growth performance and weight gain (Schalch et al. 2001). However, Aregheore (2000) observed better average daily live weight gain in animals fed citrus-pulp-based diets. It resulted in improved growth performance in Saanen kids (Bueno et al. 2002). Cows fed TMR having more DCP showed higher weight gain than those fed TMR having less DCP (Miron et al. 2002). Improved weight gain was observed in beef cattle fed DCP as compared to other treatments (Alkire 2003), which might be due to easily digestible cell wall of the citrus pulp (Madrid et al. 1997) that has positive effect on rumen microflora (Gado et al. 2009).

Citrus pulp can be used up to 30% on DM basis without any adverse effect on feed efficiency in lambs (Fung et al. 2010). The DCP reduced the cost incurred on feed when it was used to replace corn in the diets of weaned lambs. Same results were observed by Gholizadeh and Nasierian (2010), who noticed that the feed cost reduced when barley grains were replaced with DCP in the diet of Saanen kids. Use of DCP as concentrate energy source is very economical in diets of lambs (Caparra et al. 2007). This is due to the reason that citrus pulp is a waste industrial by-product with excellent nutritional value for

### Table 5. Effects of varying levels of DCP on blood metabolite in lambs.

| Blood metabolites (mg/dL) | DCP10 | DCP20 | DCP30 | DCP40 | SEM  |
|---------------------------|-------|-------|-------|-------|------|
| Blood urea                | 45.25 | 44.88 | 44.44 | 43.72 | 1.239|
| Blood urea nitrogen       | 21.14 | 20.97 | 20.77 | 20.43 | 0.510|
| Blood glucose             | 57.55 | 57.85 | 58.90 | 59.37 | 1.910|

Note: DCP10, DCP20, DCP30 and DCP40 represent low DCP, medium DCP, high DCP and very high DCP, respectively. SEM indicates standard error mean.

### Table 6. Effects of varying levels of DCP on weight gain and feed efficiency in lambs.

| Parameter | DCP10 | DCP20 | DCP30 | DCP40 | SEM  |
|-----------|-------|-------|-------|-------|------|
| Initial weight (kg) | 21.50 | 23.50 | 22.80 | 23.10 | 0.554|
| Final weight (kg)    | 29.6   | 32.66 | 31.40 | 32.20 | 0.717|
| Weight gain (kg)     | 8.10   | 9.16  | 8.60  | 9.10  | 0.636|
| Daily weight gain (g) | 67.50 | 76.33 | 71.67 | 75.83 | 1.852|
| Feed price (Rs/kg)   | 28.62  | 27.75 | 26.90 | 26.46 | —   |
| Average feed intake (kg) | 162.00 | 163.80 | 166.20 | 168.6 | 1.44|
| Feed efficiency      | 0.050  | 0.056 | 0.052 | 0.054 | 0.001|
| Price/kg live weight (Rs) | 573.38 | 496.25 | 519.94 | 490.24 | 11.81|

Note: DCP10, DCP20, DCP30 and DCP40 represent low DCP, medium DCP, high DCP and very high DCP, respectively. SEM indicates standard error mean.

Means in same row sharing different superscripts differ significantly (P < .05).
ruminants, which is cheaper than cereal grains, resulting in preparing the economical ration (Villarreal et al. 2006).

**Conclusion**

The study indicated that DCP can be used successfully up to 40% of the concentrate in the diet of lambs without any adverse effect on feed intake and growth performance. Usage of DCP in the diet resulted in cost-effective feed formulation.

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