Group sizes effects on growth performance and behavioural characteristics in Korean native calves

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ABSTRACT

Effects of group size on performance and behavioural characteristics in Hanwoo calves including heifers (BW = 140.7 ± 3.8 kg, 8 ± 0.5 month) and steers (BW = 167.2 ± 3.4 kg, 8 ± 0.6 month) were evaluated. Fifty-four calves (27 steers and 27 heifers) were assigned to three group sizes, with either 4 (G4), 3 (G3) or 2 (G2) animals per pen, with 3 pen replicates. Data obtained were analysed using the MIXED procedure of SAS. BW was measured bimonthly until the end of the study, and behavioural observations were performed weekly. In heifers, BW showed no differences (P > .05) at neither 8 nor 10 months, however, it was higher (P < .05) in the G4 than the G2 in both 12 and 14 months of age, respectively. In steers, there were no significant differences (P > .05) among the groups in BW, average daily gain, and feed conversion ratio at 8 and 10 months. In heifers, drinking, self-grooming, pairwise grooming were higher in the G4 and G3 than the G2 group (P < .05). The effect of time on performance and behavioural characteristics was highly significant (P < .01). Collectively, the number of 4 calves per pen (32 m²) can be suggested to improve growth performance in Hanwoo calves.

Introduction

Intensive farming has resulted in high stock density during the fattening phase of cattle. High stock density is documented to lead to lower performance of the animals and impairs animal welfare and behaviour. Thus it can adversely affect the immune system of the animals (Rind and Phillips 1999; Kondo 2011; Lee et al. 2012). For practical reasons and due to the labour costs, fattening Hanwoo steers are usually housed as 4–12 heads, forming a dynamic group based on their fattening characteristics and local environmental conditions (Ha et al. 2017; Yang et al. 2016). In Korea, stocking density with respect to the group size is one of the major concerns (Li et al. 2010; Lee et al. 2012) due to having over 70% mountainous areas and 12–16% arable land (Choi 2011; Park et al. 2012). Increasing stocking density can be achieved by increasing the number of animals on a given area of land, or by decreasing the amount of land accessible to animals over the same amount of time (Yang et al. 2015). This may result in high intensive farming. Moreover, the role of high stocking density on the immune system, stress responses, and behavioural characteristics of cattle has been recently reported (Broom 2003; Lee et al. 2012; Ha et al. 2016). Additionally, cattle and calves, in particular, are social animals and known to be behaviourally influenced by stocking density (Friend 2003; Lee et al. 2012; Ha et al. 2016). Collectively, the number of 4 calves per pen (32 m²) can be suggested to improve growth performance in Hanwoo calves.

Materials and methods

Experimental design, treatments, and animals

The experimental procedure and methods were approved by the Animal Welfare and Ethics Authority of Livestock Technology Research Institute, Gyeongsangbuk Province, Republic of Korea. Fifty-four calves (27 steers; 167.2 ± 3.4, 8 ± 0.6 month and 27 heifers; BW = 140.7 ± 3.8 kg, 8 ± 0.5 month) were assigned to 3 group size treatments, with either 4 (G4), 3 (G3) or 2 (G2) animals per pen, with 3 pen replicates per sex. All

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calves were housed in a full concrete slatted floor because of the low labour cost and straw bedding was provided in a fully bedded loose housing system to cover any dirty or wet patches on the concrete floor. All bedding was renewed on a monthly basis. A schematic layout of the experimental pens and animals is shown in Figure 1. Calves were originated from the same farm owned by Gyeongsangbuk-do Livestock Research Institute. Equal numbers of heifers and steers were used and were randomly assigned to each group including four, three, and two heifers per pen (32 m²) in G4, G3, and G2, respectively. The experiment was performed from April to December 2016 for eight months.

Animal management and diet

All animals were housed in a covered industrial farm with free access to water, mineral blocks, and under the same environmental conditions. The litter on the bottom of each pen was uniformly supplied at an average height of 10 cm using sawdust. Diet formulation was performed according to the Hanwoo specification management programme. Feeding occurred twice a day at 8:00 AM and 5:00 PM. Individual feeders for pen feeding were used to feed calves. Diets were fed according to the recommendations by national research council requirements for beef cattle (NRC 2000) adjusted for average body weight based on the consulting guideline for Hanwoo (KSAST 2009). The general components of nutrient contents in the experimental diets were analysed according to the method of AOAC (1990) as presented in Table 1.

Measurements

Body weights (BW) were measured bimonthly until the end of the study, and the daily gain was calculated by dividing the BW to 60 days. The feed conversion ratio was calculated by dividing feed intake by weight gain. CCTV cameras (IR LED Camera; APD-7070V, Sony, Japan) were set up on each side of the experimental house to record the behaviour of the calves throughout the experiment. In order to improve the sharpness and the observation accuracy according to the characteristics of the camera, we examined different angles of the barn to install the cameras. The method of collecting behaviour data for each treatment was based on the method of Sato et al. (1995), which is used to track the behaviour of a single entity. All groups were classified according to treatment behaviour for each age group. Behavioural observations were performed weekly from 7:00 AM to 07:00 PM, 12 h per day, based on the pre-prepared behaviour list as follows: feeding of concentrate (FC), feeding of forage (FF), standing (ST), lying down (LD), walking (WK). The behavioural characteristics for scoring the frequency included drinking (DK), self-grooming (SG), scratching (SR), rubbing (RB), pairwise grooming (PG), leaning (LN), and fighting (FT). Behavioural characteristics were observed at 2-min intervals using the time-sampling method when calves were drinking, self-grooming, licking, rubbing, pairwise grooming, leaning, and fighting recordings were analysed for each behaviour and the frequency of behavioural characteristics was scored.

![Figure 1](https://example.com/image1.png) Figure 1. Fifty-four calves (23 steers and 23 heifers) were assigned to 3 group size treatments, with either 4 (G4), 3 (G3) or 2 (G2) animals per pen, with 3 pen replicates per sex.

| Table 1 Chemical composition of feeds (DM basis) |
|-----------------------------------------------|
| Items (%) | Concentrate | Heifer calves | Steer calves | Rice straw |
| --- | --- | --- | --- | --- |
| Moisture | 11.27 | 10.91 | 7.37 |
| Crude protein | 14.96 | 15.15 | 4.31 |
| Crude fibre | 3.61 | 4.76 | 27.98 |
| Crude fat | 3.46 | 2.88 | 1.84 |
| Crude ash | 7.14 | 7.48 | 8.36 |
| Nitrogen-free extract | 59.56 | 58.82 | 50.14 |
| Calcium | 1.02 | 1.23 | 0.35 |
| Phosphorus | 0.53 | 0.56 | 0.14 |
| Neutral detergent fibre | 25.45 | 25.72 | 66.06 |
| Acid detergent fibre | 11.22 | 11.16 | 41.33 |
| Total digestible nutrients | 68.73 | 69.87 | 45.02 |
Statistics

All calves were randomly assigned to each pen as a block and to the treatment group. Statistical analysis was carried out using the MIXED procedure of SAS (Version 9.1; SAS Institute Inc., Cary, NC) with time and group as fixed effects and animal × treatment (group) as a random effect. Variance and covariance assumption structures (AR(1), UN, CS, etc.) were tested, then AR (1) as the best covariance structure for final analysis was selected. The Tukey means comparison was used for multiple range comparisons. Following these analyses, two-way GLM procedure was applied separately for bimonthly observations. Statistical differences were considered significant at P < 0.05. The normality of the data for its distribution was tested before the application of the final comparison by SAS. Initial body weight as a covariate was included in the model when appropriate but, was removed from the model when it was not significantly different. Hanwoo calves including heifers and steers were characterized differently and received two different rations with free access to rice straw. Therefore, instead of including the possible sex effect, we aimed not to mix the data and had them separately analysed. Thus obtained results were reported in separate tables.

Results

Growth performance

The effect of time was highly significant (P < 0.01) among the groups whereas the interaction effect of time * group were significant (P > 0.05) in performance results including BW, ADG, and the FCR for both sexes.

In heifers (Table 2), body weight (BW) showed no significant differences (P > 0.05) at 8 nor 10 months of age. However, BW was higher (P < 0.05) in the G4 than the G2 in both 12 and 14 months of age, respectively. There were no significant differences (P > 0.05) in BW between the 2 groups at 12 and 14 months between G4 and G3 nor between G3 and G2 (Table 2) except for the 14 months in ADG between G3 vs. G2 (P < 0.05). Except for the second sampling time (10 months), the average daily gain (ADG) and feed conversion ratio (FCR) were higher (P < 0.05) and lower (P > 0.05) in G4 than in G2 whereas no significant differences (P > 0.05) were observed between G4 and G3 nor between G3 and G2 (Table 2).

In steers (Table 3) there were no differences (P > 0.05) among G4, G3, and G2 in BW, ADG, and FCR at 8 and 10 months. In 12 and 14 months, higher (P < 0.05) BW were observed in the G4 than the G3 and G2 whereas G3 showed higher (P < 0.05) BW than in G2 as well (Table 3). Accordingly, similar results of ADG and FCR as heifers were observed at 12 and 14 months (Table 3).

Behavioural characteristics

In heifers (Table 4), the effect of time was highly significant among all behavioural characteristics. Effects of interaction between time × group were not significant (P > 0.05) in standing and lying down heifers whereas other interactions resulted in either highly significant (P < 0.01) or significant (P < 0.05) differences (Table 4). The frequency (no./12 h) of drinking, self-grooming, and pairwise grooming was higher (P < 0.05) in G4 and G3 than in G2 (Table 4). As the size of the groups got smaller, from G4 to G2, the number of fighting behaviour decreased (P < 0.05). Group size had no significant (P > 0.05) effects on scratching behaviour, rubbing behaviour, and leaning behaviour of heifers among G4, G3, and G2 (Table 4).

In steers (Table 5), higher number of steers in pen resulted in significantly (P < 0.05) more time spending on walking behaviour. Lying behaviour of steers was the highest in G3 (P < 0.05). Standing time was lower (P < 0.05) in G2 and G3 whereas no differences (P > 0.05) were observed between either G4 or G3 or between G4 and G2 (Table 5). No differences (P > 0.05) were observed in the number of self-grooming, scratching, and

Table 2. Effect of group size on feed intake and growth performance of heifer calves.

| Age          | FI (kg/head) | BW (kg) | ADG (kg) | FCR |
|--------------|--------------|---------|----------|-----|
|              |              |         |          |     |
| 8 mt.        |              |         |          |     |
| G4           | 2.5          | 2.5     | 171.63 ± 4.85 | 0.52 ± 0.04a | 7.89 ± 0.62b |
| G3           | 168.50 ± 6.61 | 0.47 ± 0.06ab | 8.87 ± 1.46ab |
| G2           | 165.50 ± 7.07 | 0.40 ± 0.04ab | 10.39 ± 1.08a |
| 10 mt.       |              |         |          |     |
| G4           | 2.5          | 2.5     | 192.25 ± 5.24 | 0.34 ± 0.14 | 14.58 ± 4.65 |
| G3           | 190.33 ± 2.84 | 0.36 ± 0.08 | 12.81 ± 2.42 |
| G2           | 189.00 ± 4.95 | 0.39 ± 0.04 | 11.64 ± 1.05 |
| 12 mt.       |              |         |          |     |
| G4           | 3            | 3       | 218.75 ± 3.97a | 0.44 ± 0.03a | 10.31 ± 0.64ab |
| G3           | 214.17 ± 5.06ab | 0.40 ± 0.04ab | 11.50 ± 1.09ab |
| G2           | 209.75 ± 2.47b | 0.35 ± 0.04a | 13.22 ± 1.58a |
| 14 mt. (Final)|              |         |          |     |
| G4           | 3            | 3       | 242.13 ± 4.09a | 0.39 ± 0.01a | 13.97 ± 0.38b |
| G3           | 236.67 ± 4.65ab | 0.38 ± 0.01a | 14.51 ± 0.32b |
| G2           | 230.50 ± 3.54b | 0.35 ± 0.02ab | 15.75 ± 0.81a |

Time: ns ns ns
Time × group: ns ns ns

Notes: Values are the mean ± standard deviation. **: Not significant. *P < .05. 1Feed intake, 2Concentrate, 3Rice straw, 4Body weight, 5Average daily gain, 6Feed conversion rate.

**Means within a column followed by a different letter are significantly different.
pairwise grooming among the group size and the result was similar with the heifers (Table 5) except for differences in self-grooming in heifers among the groups. Drinking behaviour and fighting behaviour were higher \((P < .05)\) as the group size increased (Table 5). Leaning behaviour was the highest \((P < .05)\) in G3 and was higher \((P < .05)\) in G4 than G2 as well. Steers in the G3 did significantly more \((P < .05)\) number of rubbing than G2 (Table 5), while G4 was intermediate and not significantly different \((P > .05)\) from either G3 or G2.

### Discussions

#### Growth performance

Hanwoo cattle are characterized as a traditional species for beef market (Yang et al. 2015). Furthermore, Hanwoo is known to have lower growth rate than the Holstein (Kang et al. 2017). These characteristics in addition to a good quality of beef and marbling scores have resulted in Hanwoo beef being the second most expensive beef after the Japanese black cattle. Hanwoo calves in our experiment showed significant increase in growth rate after 10 months when they had developed rumen and could have higher dry matter intake. This may explain the effect of time on BW, ADG, and FCR in the current study. However, the effect was lower in heifers and higher in steer calves meaning that sex can be another influencing factor. Results obtained showed that although BW and ADG were increasing as time passed, steers weighed higher than the same age heifers. The effect of time in performance was highly significant as it was expected due to higher feed intake and rumen development efficiency in both heifers and steers. However, the interaction of time × group was not significant (Tables 2 and 3). Calves were growing daily by increasing the volume of the gastro-intestinal tract (GIT) which resulted in improving feed efficiency and higher dry matter intake. Feed efficiency and higher DMI can be postulated to noteworthy improvements in BW and consequently the ADG of the calves from 10 months and higher age. Both heifers and steers showed higher BW, ADG, and lower FCR as the number of calves increased from 2 heads to 4 heads linearly particularly after 10 months when having a developed GIT. The phenomena could be supported according to the behaviour of social aspects of the group size.

#### Table 3. Effect of group size on feed intake and growth performance of steer calves.

| Age (mt) | Grouping | FI\(^1\) (kg/head) | BW\(^3\) (kg) | ADG\(^5\) (kg) | FCR\(^6\) |
|---------|----------|---------------------|--------------|---------------|-----------|
|         | G4 3.5 2.5 | 213.00 ± 9.94 ns | 0.77 ± 0.08 ns | 6.55 ± 0.71 ns |
|         | G3 4 2.5   | 210.33 ± 9.41 ns | 0.72 ± 0.11 ns | 7.06 ± 1.19 ns |
|         | G2 2       | 208.25 ± 10.25 ns | 0.68 ± 0.14 ns | 7.56 ± 1.58 ns |
| 10 mt.  |           | 258.63 ± 4.48 ns | 0.76 ± 0.11 ns | 7.27 ± 1.07 ns |
|         | G3 3       | 255.83 ± 4.25 ns | 0.76 ± 0.17 ns | 7.41 ± 1.58 ns |
|         | G2 2       | 253.25 ± 4.60 ns | 0.75 ± 0.09 ns | 7.31 ± 0.92 ns |
| 12 mt.  |           | 315.88 ± 1.89a | 0.95 ± 0.05a | 6.66 ± 0.33b |
|         | G3 3       | 309.67 ± 3.55b | 0.90 ± 0.06ab | 7.09 ± 0.46ab |
|         | G2 2       | 303.75 ± 2.47b | 0.84 ± 0.04ab | 7.54 ± 0.33a |
| 14 mt.  |           | 366.00 ± 3.03a | 0.84 ± 0.02a | 8.13 ± 0.22b |
|         | G3 3       | 359.00 ± 3.00b | 0.82 ± 0.01ab | 8.26 ± 0.13ab |
|         | G2 2       | 351.50 ± 2.12c | 0.80 ± 0.01b | 8.53 ± 0.06a |

Notes: Values are the mean ± standard deviation. ns: Not significant. \(* P < .05\). \(^{1}\)Feed intake, \(^{2}\)Concentrate, \(^{3}\)Rice straw, \(^{4}\)Body weight, \(^{5}\)Average daily gain, \(^{6}\)Feed conversion rate.

\(a\)–\(c\)Means within a column followed by a different letter are significantly different.

#### Table 4. Effect of group size on behavioural characteristics of heifer calves.

| Items                  | Age (min/12 h) | G4          | G3          | G2          | Time | Time × group |
|------------------------|----------------|-------------|-------------|-------------|------|-------------|
| Feeding                | Time           | 19.63 ± 7.86 ns | 21.75 ± 6.44 ns | 21.00 ± 7.62 ns | **   | *           |
|                        | RS\(^5\)       | 40.75 ± 13.66 ns | 37.48 ± 11.15 ns | 45.31 ± 15.36 ns | **   | *           |
| Standing               | Time           | 389.59 ± 30.29 ns | 373.50 ± 35.36 ns | 397.25 ± 34.66 ns | **   | ns          |
|                        | Lying down     | 256.47 ± 21.30 ns | 272.38 ± 36.95a | 240.41 ± 33.11b | **   | ns          |
|                        | Walking        | 13.56 ± 2.94 ns | 14.90 ± 3.87 ns | 16.03 ± 3.85 ns | **   | *           |
| Count (number/12 h)    | Time           | 13.25 ± 4.30a | 11.81 ± 3.73a | 8.22 ± 3.77b | **   | *           |
|                        | RS\(^5\)       | 23.50 ± 6.27a | 24.35 ± 8.56a | 18.22 ± 7.05b | **   | *           |
| Drinking               | Time           | 2.51 ± 0.87 ns | 2.26 ± 0.97 ns | 2.18 ± 0.95 ns | **   | *           |
|                        | RS\(^5\)       | 15.49 ± 2.94 ns | 16.99 ± 3.24 ns | 15.22 ± 3.05 ns | **   | *           |
| Self-grooming          | Time           | 15.25 ± 3.49a | 16.21 ± 3.75a | 8.72 ± 3.83b | **   | *           |
|                        | RS\(^5\)       | 8.77 ± 3.29a | 8.71 ± 1.97b | 9.63 ± 3.77 b | **   | *           |
| Pairwise Grooming      | Time           | 5.63 ± 1.90a | 3.23 ± 1.14a | 1.41 ± 1.10a | **   | *           |

Notes: Values are the mean ± standard deviation. ns: Not significant. \(^{1}\)Concentrate, \(^{2}\)Rice straw.

\(a\)–\(c\)Means within a row followed by a different letter are significantly different \((P < .05)\).
competition, which would accelerate eating with other peer mate behaviour. Given that four heads per 32 m² caused higher fighting for feed may have also attributed to the obtained results on growth performance. Fighting for feed is a behaviour that may cause higher feed competition. The results of this study are consistent with other studies that reported similar results in the performance of growing heifers (Vendramini et al. 2015) and dairy cattle (Lobeck-Luchterhand et al. 2015). Hanwoo calves are social animals and thus higher numbers of calves in one group may increase fighting behaviour in calves as we observed in this study. However, to some extent, it may not decrease the productivity of the animals. Hence, the question regarding the numbers of calves that cause a decrease in productivity of the animals needs to be investigated in future studies.

From obtained results on growth performance, and given the economic values of the land use perspective, we could conclude that higher group size in this study (4 heads of calves per 32 m² area) is suitable for growing Hanwoo calves from the age of 8–14 months.

**Behavioural characteristics**

Previous studies (Sandhage et al. 1983; Dellmeier et al. 1985; Veissier et al. 1994) reported higher individual variability in the behaviour of calves, particularly the amounts of time spent standing and lying down. It is considered that the difference in behavioural characteristics according to the number of calves depends on the size of the barn over the breeding of calves. According to Wilson et al. (1999), there was no consistent difference in the behaviour of the Holstein calves from week 4 to 18 whether they were kept in open stalls or in individual pens. The results of the present study are consistent with the previous findings (Wilson et al. 1999; Kim et al. 2002) for feeding, standing, and walking behaviour in heifers and feeding behaviour in steers. However, more walking and less time spent lying down behaviour was observed in steers of G4 and G2, respectively. This was similar to the study of Li et al. (2010) on Hanwoo steers in groups of 4, 8, and 12 calves per area (8.4 × 4.2 m, 8.4 × 8.4 m, and 12.6 × 8.4 m). As expected, the effects of time and the interaction of time×group in both heifers and steers were significant except for standing and lying down behaviour concluding that as time passes from 8 to 14 months, the behaviour of the calves will be changed. However, the effect of time and its interaction with group size not being significant in both heifers and steers in this study during the experimental period remained unknown to the author.

Regarding behaviour frequency, G4 showed higher values than G2 and G3 groups in self-licking and licking. These behaviour characteristics are good measures of cattle health and growth and are necessary actions to maintain body health (Albright and Arave 1997; Kim et al. 2002). Higher self-licking in heifers in G2 than the other groups might be due to the fact that cattle are sociable animals and this behaviour is a sign that there is less number of animals available for interaction in the same group. As the number of steers increased body rubbing, body leaning, and fighting behaviours increased, and these behaviours were more common in young calves (KSAST 2009), which are pivotal behavioural factors in cattle growth and development. Generally, a lower number of calves per area contributes to social stability (Albright and Arave 1997). It has been reported that lower number of animals may lead to lower aggression behaviour than the higher numbers in a group, and therefore the aggression may increase linearly as the number of the animals per area increased (Kondo et al. 1989). This may be explained by the animals having much difficulty in individual recognition as the number of animal per the same area increases. In the current study, similar results were found in fighting behaviour in both heifers and steers as the number of calves increased. Similar phenomena could be attributed to the drinking behaviour particularly when the size of water trough is small. This may explain the linear increase in the number of drinking as the number of animals per area decreased. As a result, it has been stated that the group size and the space area are causes of social behaviour changes in calves and dairy cows (Kondo and Nishino 1983; Rind and Phillips 1999). Overall, in this study, individual behaviours appeared to be vigorous in the calves of G4 and thus it could be suggested that four calves may be accommodated in 32 m² space considering the economic specifications. Our results showed that four calves in each group did not decrease performance of the animals while increased fighting behaviour. Thus, although smaller number of calves may decrease fighting behaviour, how many calves in each

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**Table 5. Effect of group size on behavioural characteristics of steer calves.**

| Items          | Count (number/12 h) | Drinking | Self-grooming | Scratching | Rubbing | Pairwise grooming | Leaning | Fighting |
|---------------|---------------------|----------|---------------|------------|---------|-------------------|---------|----------|
|               |                     | G4       | G3            | G2         | Time    | Time × group     |         | Time     |
| Feeding       |                     | 13.89 ± 3.33      | 11.19 ± 3.74  | 9.03 ± 3.06| **      | **               |         | **       |
| Concentrate   | 19.38 ± 6.00        | 18.65 ± 3.21  | 18.19 ± 4.35  | **         | **      | **               |         | **       |
| Rice straw    | 3.38 ± 0.95         | 3.24 ± 1.17   | 2.94 ± 1.81   | **         | **      | **               |         | **       |
| Standing      | 13.83 ± 2.55        | 12.69 ± 2.64  | 11.59 ± 1.87  | **         | **      | **               |         | **       |
| Lying down    | 15.42 ± 3.60        | 14.44 ± 2.42  | 13.38 ± 2.58  | **         | **      | **               |         | **       |
| Walking       | 8.47 ± 3.17         | 10.63 ± 2.68  | 6.41 ± 1.39   | **         | **      | **               |         | **       |
| Count (number/12 h) | 14.27 ± 2.35      | 8.06 ± 2.10  | 4.13 ± 1.82   | **         | **      | **               |         | **       |

Notes: Values are the mean ± standard deviation. **: Not significant. 1) Concentrate, 2) Rice straw.

*a,b*: Means within a row followed by a different letter are significantly different (P < .05).
group (same area) may cause adversely affect the performance of the animals needs further investigations.

Conclusions
Collectively, we suggest that the number of 4 calves per pen (32 m²) is more advisable than 3 and 2 for both heifers and steers for the age range of 8–14 months to improve growth performance. Hanwoo is a social animal and thus larger numbers in a group may cause increased fighting behaviour which may not necessarily decrease their performance. The results of this study can be used as basic data for the management of eco-friendly breeding of Korean Hanwoo cattle that comply with welfare considerations and high performances. Future experiments having a different group size of Hanwoo cattle would be recommended.

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No potential conflict of interest was reported by the authors.

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