Comparative evaluation of behaviour of Holstein-Friesian and Jersey cows under European pasture-based management systems

Thesis report

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Period: March – August 2017

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WAGENINGEN UNIVERSITY & RESEARCH

Comparative evaluation of behaviour of Holstein-Friesian and Jersey cows under European pasture-based management systems

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Course code: FSE – 80430

Credits: 30

Period: March – August 2017

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Preface and acknowledgement

It has been a great privilege to spend two years discussing and thinking about global farming systems at Wageningen University and Research (WUR). Definitely, I have gained sufficient knowledge and skills in multidisciplinary issues from WUR and broadened my capacity in conducting research. The accomplishment of coursework and MSc thesis would not have been possible without the NFP financial support and invaluable contribution from different people, and I would like to acknowledge all for their support and inspiration.

I am grateful to dr.ir. Lantinga for agreeing to conduct my MSc thesis under his supervision at Farming System Ecology (FSE) group. Egbert, I was inspired with your interest on grazing cows and sharing your additional experience on meteorology and climate change. You have always encouraged me to think about the alternative options throughout my stay at FSE, thank you for your contribution to my research career.

Special thanks to dr.ir. CG (Kees) van Reenen from the Wageningen Livestock Research, for his brilliant supervision throughout my MSc thesis. Kees, I would like to thank you for accepting me to work under your supervision despite your tight schedule. Thank you for granting access to the data involved in my thesis study, and genuine support during data analysis. Your commitment and positive attitude towards research, among others, are the great inspiration to me. You have set an example of excellence to me as a great research scientist in the near future.

This MSc thesis would not have been possible without the data collected from the experimental dairy farm in Zegveld, Utrecht under the project "Amazing Grazing 2016", coordinated by Wageningen Livestock Research. Therefore, I would like to extend my sincere gratitude to all technical staffs and project team involved. Special thanks to ing. AP (Bert) Philipsen, the project manager of the Amazing Grazing Project, for his support and connections to Kees van Reenen. Also, I would like to thank ing. Joop van der Werf for his technical support in providing additional data from Zegveld farm.

Completing this work would have been more difficult without the support from my family, relatives and friends for their support, encouragement and prayers. I must expand deeply grateful to my wife Nandera and daughter, Lisa Wilson for their love, prayers, support and patience during my absence. Prima facie, I am grateful to the Almighty God for his guidance, good health and ability to conduct this study successfully.

Lastly, I would like to dedicate this thesis to my late grandfather Rev. Patrick Ashery Mndalila who encouraged me in my academic career, and beloved aunt Alice Patrick Mndalila who passed away during my MSc studies. I hope that they would have been proud to see me achieving my MSc abroad. May their souls rest in eternal peace.

Abstract

In dairy farming, it is essential to observe behavioural and physiological changes of cows as early as possible to ensure better health, welfare and productivity. The objective of the current study was to investigate whether the differences in grazing behaviour exist between Jersey (Jer) and Holstein Friesian (HF) cows under pasture-based management systems. The behavioural activities of 62 lactating dairy cows (36 HF and 26 Jersey cows) at Zegveld research unit, was recorded by the ear tag microchip, sensOor (AGIS, Automatisering) and the SmartTag neck sensor (NEDAP, The Netherlands) from April to October 2016. The activities recorded by sensOor included eating/grazing and rumination while the NEDAP recorded eating/grazing and standing indoors and on pastures, respectively. Furthermore, the current study included two grazing systems kurzrasenweide (KR) and strip grazing (SG) and two levels of degradable proteins (OEB+ and OEB-). The differences in dietary level were created by supplementing the cows with 6 kg of concentrates per day with either an OEB+/- value of -50 or +50 g/kg DM according to DVE/OEB2007 protein evaluation system for dairy cows. The hypothesis tested was Jersey cows perform better under grazing condition as compared to the HF cows and also, supplementation with low degradable protein might have increased the time spent in grazing as compared to high degradable protein. The behavioural data and performance evaluation were coded and analysed by Genstat 18th edition and Statistical Package for Social Sciences version 23, respectively.

The mean BW, FPCM and daily NEL,required was significantly lower for Jersey cows as compared to HF in all experimental groups, throughout the experimental period (p-value ≤0.05). The NEDAP output shows significant differences in the time spent eating/grazing and standing indoors and on pastures. However, with an exception for rumination activities, the current version of sensOor was overestimating and unable to differentiate between eating concentrate/roughages indoors and grazing on pastures. Based on the sensOor output HF cows spent longer time in rumination as compared to Jersey cows throughout the experimental period. NEDAP output shows that Jersey cows spent longer time in standing, associated with their smaller body size and less energy requirements. Also, Jersey cows spent longer time in eating/grazing as compared to HF, both indoor and outdoor, associated with higher intake capacity per kg body weight. Unlike Jersey cows, the time spent in grazing by the HF varied between the grazing systems. When cows were on grazing in June and August, HF spent short time in grazing under SG as compared to KR system, which is associated with the quality of pastures.

On the other hand, when cows were on pastures Jersey cows were not affected by changing the protein level in diet, which influenced their consistency in percentage time spent on grazing in both KR and SG systems. However, HF were affected by reducing the protein level in diet, associated with their higher energy requirements for maintenance and production. The persistence of Jersey cows under low protein levels and the higher efficiency in grazing provides an opportunity for reducing the costs of production and feed-food competition for cereals, required for human and monogastric animals. The use of sensor technology could be an early warning tool in monitoring behavioural activities of cows. However, further improvement of the sensOor is required to avoid overestimation of behaviour activities and to differentiate between eating and grazing. The use of sensor technology might be useful to both farmers and researchers in reducing time spent on monitoring behavioural activities of individual cows.

Key words: grazing, behaviour, Jersey, sensOor, NEDAP

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1 Introduction

1.1. Background

Milk production of dairy cows has increased substantially over the last 50 years, especially in industrialized countries (Fulkerson et al., 2008). However, the productivity level varies between breeds of cattle and the production system (Dillon et al., 2003a). The genetic differences among breeds of cattle are developed through different breeding goals over a period of time. Genetic selection programs that were entirely based on increasing milk production for a long time have led to a decrease in genetic variability in the cattle population (Maurice-Van Eijndhoven et al., 2015). Furthermore, the aggressive genetic selection for milk production has led to the increase in incidences of nutritional disorders and metabolic problems, where cows are predisposed to higher risks of dietary energy deficit particularly during the early lactation period (Delaby et al., 2009; Walsh et al., 2008).

The specialised dairy breeds such as the Holstein Friesian and Jersey contributes a large proportion of milk produced in USA and Europe. However, there are variations in milk yield, milk composition and body weight between these breeds (Dillon et al., 2003a). The one-way selection program for milk production has led to a decline in the use of native dual-purpose cattle breeds, which have been used for both milk and beef production. For the last 30 years, the percentage of Dutch native dual purpose cows has declined from 91.3% to 1.4% (Maurice-Van Eijndhoven et al., 2015). Currently, Holstein Friesian dominates the dairy cattle population by 95% and 98% in Europe and The Netherlands, respectively (Kaptijn and Lantinga, 2016; van Arendonk and Liinamo, 2003). The common strategy of replacing the native dual-purpose cattle breeds with Holstein Friesian is also referred to as the "Holsteinization". The Holsteinization process contributes to the decline in number of local dual-purpose cattle breeds in The Netherlands, that produce less milk but are well adapted to the local environment (Groot and van't Hooft, 2016).

The specialised selection of Holstein Friesian for higher milk yield has increased feed requirements throughout their production lactation period, and resulted in deterioration of other important functional traits such as reproduction performance, health and longevity (Dillon et al., 2003b). The one-way selection for higher milk yield was associated with increased cases of lameness, metabolic problems and mastitis, which contributed to modification of normal behaviour of cows and reduced animal welfare (Oltenacu and Broom, 2010). Furthermore, selection for higher milk production has been done in a predominantly feedlot environment, and it is still questionable whether Holstein Friesian cows could perform better under optimal grazing condition (McCarthy et al., 2007a).

In recent years there was a rapid increase in societal interest on pasture-based milk production systems in most industrialized countries especially in USA and Europe (Dillon et al., 2005; Sahota, 2009). Pasture-based production system is an important aspect of the organic dairy production system (IFOAM, 2005), and is considered as the most effective means of reducing costs of milk production when managed properly (Delaby et al., 2001; Kennedy et al., 2003). Furthermore, pasture-based production systems contribute in reducing feed-food competition due to the reduced amount of cereals, which are also required for humans and monogastric animals (Heublein et al., 2016). On the other hand, pasture-based production system requires a well-adapted dairy cattle breed with high efficiency in converting energy intake to milk production (Buckley et al., 2005; Prendiville et al., 2010). However, most breeding programs placed emphasize on production performance, survival and functional (health and reproduction) traits (Miglior et al., 2005). Nevertheless, less attention was placed on incorporating feed intake and feed conversional efficiency during selection processes (Prendiville, 2009).

The demand for organic-source foods is rapidly increasing globally (Campbell et al., 2013). In 2014, the largest organic markets were reported in the United States, European Union and China, accounting for approximately 43%, 38% and 6% of the global market, respectively (Willer and Lernoud, 2016). The highest per capita consumption of organic products was reported in Switzerland, Denmark, Luxembourg, Austria, Sweden and Germany (Willer and Lernoud, 2016; Willer and Schaack, 2015). On the other hand, the sales of organic products in the Netherlands increased for about 70% in the period between 2009 to 2013 (van Asselt et al., 2015). However, the current demand for organic products in the Netherlands is higher than the domestic production and supply (Willer and Schaack, 2015). For example, in 2012 there was a shortage of about 40 million litres of organic milk in Netherland. This, in turn, leads to increased imports of organic milk from abroad. The current shortage of organic dairy products in the country provides a considerable room for farmers to convert to organic farming, in order to meet the increasing market demand. Currently, 70% of the dairy cows are grazed in the Netherlands, however, the number is decreasing particularly in farms with large herds of cattle (Zom et al., 2016). This trend is associated with the increase in intensification, atomization of farms (Klootwijk et al., 2015; Van den Pol-van Dasselaar, 2015) and difficulties in grazing management due to the increased herd size and stocking rate (Rutten, 2017; Van Reenen et al., 2016). The number of dairy farms in the country has decreased by 38% i.e. from 29,000 farms in 2000 to about 18,000 farms in 2015. Similarly, the stocking density per farm in the country has increased for about 74% i.e. from 50 dairy cows/farm in 2000 to about 89 cows/per farm in the year 2015 (Rutten, 2017).

The rapid increase in demand for organic dairy products is associated with the increase in public awareness and concern on environmental issues, healthy foods and animal welfare (Bloksma et al., 2008; Hörtenhuber et al., 2010; van Asselt et al., 2015). Pasture-based productions systems provide an opportunity for cows to express natural behaviour, and recent research reported that herds with summer pasturing had less prevalence of lameness, lesions and swellings as compared to zero-grazing (De Vries et al., 2015). According to the IFOAM (2005), organic dairy farming has many beneficial values that support the ecosystem, health of the soil and human beings. The use of natural manure instead of chemical fertilisers and restricted use of chemical drugs reduces environmental contamination and stimulates soil life, which generates more food for soil organisms and improves biodiversity (Raeijmaeckers, 2015). Furthermore, the organic chain implies that a healthy soil leads to healthy grasses, which results to healthy cows that produce healthy milk, which in turn leads to healthy consumers (Bloksma et al., 2008).

The grass-based milk is distinguishable from conventional milk, characterised by higher levels of poly-unsaturated fatty acids (PUFA) and vitamins particularly vitamin A, E and β-Carotene (Hospers-Brands and van der Burgt, 2009; Kučević et al., 2016). The higher level of PUFA, particularly the conjugated linoleic acid (CLA) and omega-3 fatty acids are considered for their beneficial health impact because they improve carbohydrate and fat metabolism. Both have positive effects on reducing cardiovascular diseases, developing cancer and reducing eczema. These beneficial aspects of organic milk are mainly associated with grazing of cows on the freshly and healthy grasses (de Wit and de Vries, 2008; Raeijmaeckers, 2015). On the other hand, the Dutch consumers indicated that they prefer organic dairy products because of better taste, quality and freshness, decreased transport mileage, higher reliability and being better for the environment (van Asselt et al., 2015).

Milk production under pasture-based production system is limited by different environmental factors, management and the capacity of the cow to consume adequate quantity of herbage (McCarthy et al., 2007a; Prendiville et al., 2010). Herbage intake is determined by the combination of the rate of biting, dry matter intake (DMI) per bite and the time spent on grazing (Prendiville et al., 2010). Furthermore, low performance of cows under pasture-based system is associated with low voluntary herbage intake and low nutrient levels required by lactating cows (Kennedy et al., 2003; Stakelum and Dillon, 2003). Lactating cows require concentrate supplementation, especially when grazed on herbage of low nutritive value. However, the amount of concentrate given to lactating cows depends on the amount and quality of grasses, stage of lactation, and the type and quality of concentrate supplements (Kennedy et al., 2003). Previous research suggested that seasonal calving, when applied efficiently, could be an effective way of ensuring dairy cows productivity on the pasture-based production systems. This can be achieved by targeting calving dates to coincide with the start of the growing season of grasses to ensure sufficient herbage supply (Dillon et al., 2003a; Walsh et al., 2008).

The ideal dairy cow breed for pasture-based production system should be capable of maintaining body condition, milk yield and a timely calving interval throughout the production period (Buckley et al., 2005; Prendiville et al., 2010). Dairy cows with higher DM intake capacities have increased grazing time and a higher rate of intake per unit of body weight (Prendiville et al., 2010). McCarthy et al.

(2006) reported that grazing behaviour differs between different strains of Friesian cows, whereby the New Zealand Friesian spent longer time in grazing but had lower biting rates compared to the Holstein Friesian cows. Furthermore, the increase in biting rates between HF strains is associated with the increase in milk yield (Bargo et al., 2002; McCarthy et al., 2007b). According to Pendville et al. (2010) Holstein Friesian cows had more mastication during rumination and they spent more time ruminating as compared to Jersey cows. On the other hand, Prendville et al. (2009) reported that Jersey cows are suitable for the predominant pasture-based production system due to their small size and large feed-intake capacity. Jersey cows require less energy and are capable of producing higher yields of milk solids per unit area as compared to Holstein Friesian cows (Goddard and Grainger, 2004; Prendiville et al., 2010).

Several technologies have been developed in different countries to monitor cow activity patterns and ruminating behaviour (Goldhawk et al., 2013; Rutter et al., 1997; Schirmann et al., 2009). Some of the automatic-monitoring systems include the SmartTag leg (leg sensor) for registration of standing, lying down and walking; the SmartTag neck (neck sensor) for registration of grazing /galling (Roelofs et al., 2017; Van Reenen et al., 2016); the RumiWatch system that register rumination, eating, drinking behaviour and locomotion (Zehner et al., 2012); and sensOor (AGIS, Automatiserng BV Harmelen, the Netherlands) for registering grazing eating, ruminating and whether a cow is active or not active.

1.2. Problem statement and justification

Precision dairy farming requires technologies that can reduce or replace the amount of labour and ensuring efficient use of other resources (e.g. feeds, pastures) while improving animal health and production (Rutten, 2017). In dairy farming, it is essential to observe behavioural and physiological changes of cows as early as possible. Close observation of individual cows is the basis for the healthy herd and contribute to minimising the costs and losses associated with health problems and a decrease in milk yield, respectively. However, most of the aforementioned technologies are less efficient since they can measure only a limited number of cow behaviour, predominantly under grazing condition (Bikker et al., 2014). Hence, further research is required to improve the tools or combining two or more technologies for successful monitoring of grazing behaviour of cattle under grazing condition.

In recent years, a monitoring system sensOor (AGIS, Automatisering BV Harmelen, the Netherlands) was introduced. The sensOor technology can record cow's behaviour, health and welfare traits in the close interval. Also, the sensOor records ear temperature and activities performed by cow i.e. grazing, eating, ruminating and whether a cow is active/not active (Kaptijn and Lantinga, 2016; König, 2016). The sensOor system was successfully validated under zero-grazing (Bikker et al., 2014) and under grazing conditions, and used to compare the behaviour of Holstein Friesian and Dutch Friesian cows (Kaptijn and Lantinga, 2016). However, the output of the sensOor didn't show significant behavioural differences between the two breeds under optimal grazing condition. Also, the sensOor were unable to differentiate between; grazing outdoors and eating roughages/concentrates indoor; whether a cow is shaking head or ears and grazing/eating; and rumination while standing or lying down. This calls for further improvements of the system for efficient monitoring of grazing behaviour of cows (Kaptijn and Lantinga, 2016). On the other hand, the SmartTag Neck sensor (NEDAP, the Netherlands) was successfully validated under grazing condition and used to register activities of HF cows i.e. standing, lying and number of steps, respectively (Van Reenen et al., 2016). This calls for further research for the assessment and application of the tool in monitoring grazing behaviour of different breeds of cows under pasture condition.

Nevertheless, literature studies suggested that the selection of HF cows for higher milk production is correlated to higher herbage intake and hence they might spend more time in grazing (Bargo et al., 2002; Kaptijn and Lantinga, 2016; McCarthy et al., 2007b). On the other hand, research suggested that Jersey cows perform better under grazing condition due to their small body size and a large digestive tract per unit live weight as compared to HF (Goddard and Grainger, 2004; Prendiville, 2009). There is, therefore, some justification for conducting further studies to explore different factors that may influence the behavioural differences between the breeds of cattle under European pasture-based system. The possible improvements could be attained by either combining the sensOor with either RumiWatch, neck sensor and/or leg sensor in order to differentiate between grazing and eating, and rumination activities. Few studies have compared the grazing behaviour of Jersey and HF cows under pasture-based production systems. Most studies have compared the behaviour of Jersey and HF cows indoor, under total mixed ration (TMR) (Aikman et al., 2008; Palladino et al., 2010).

1.3. Objectives

The main objective of the current study was to investigate whether the differences in grazing behaviour exist between Jersey and HF cows under Netherlands pasture-based management systems. The first hypothesis tested was "Jersey cows perform better under grazing condition as compared to the HF cows in terms of percentage time spent in grazing, herbage intake and rumination". The second hypothesis was "cows given low protein concentrate spent longer time in grazing as compared to high protein diet".

1.4. Research questions

The comparative evaluation of the two breeds of cattle under pasture-based management systems will be achieved through answering the following research questions: -

1) What are the differences in eating/grazing behaviour between the Jersey and HF breeds indoor and on pastures?
2) What is the influence of grazing system on grazing behaviour of Jersey and HF cows?
3) What are the effects of changing diet level (protein level) on time spent on eating/grazing for Jersey and HF cows?
4) What are the differences in ruminating time/behaviour between Jersey and HF cows?
5) What are the effectiveness of the sensOor and NEDAP in monitoring activities of cows under pasture condition?

2 Materials and methods

2.1 Background information of the experiment

The current study involved the primary data collected from the experimental dairy farm in Zegveld, Utrecht under the project "Amazing Grazing", coordinated by Wageningen Livestock Research. A total of 62 dairy cows (36 HF and 26 Jersey cows) were installed with two types of sensors for monitoring behavioural activities. The sensors include: - the ear tag microchip, sensOor (AGIS, Automatiserng BV Harmelen, the Netherlands) for registration of cow's behaviour i.e. eating/grazing and rumination; and the SmartTag neck sensor (NEDAP, the Netherlands) for registration of grazing/eating and standing. The SensOor is installed in the left ear (orange button) and the SmartTag neck sensor at the bottom of a collar neck, just behind the chin (Figure 1) (AmazingGrazing, 2017). The automated microchip sensOor (AGIS) and NEDAP were installed to dairy cows in Zegveld farm on April 18, 2016. The sensOor data were collected from May to October 2016, while the NEDAP data included the behavioural activities from June to October 2016. However, data from cow 92 (SG-H) and 135 (KR-H) was dropped due to some technical problems observed from the output. Cows under SG-H and SG-L were held on stable from June 23 to June 27, 2016, due to excessive rainfall. Also, cows under SG-H and SG-L were held on stable from September 30th to October 11th, and October 2nd to 11th respectively, due to insufficient grasses.

Figure 1. HF and Jersey cows equipped with SensOor (AGIS) and SmartTag neck (NEDAP) at PTC Zegveld

2.2 Description of the experimental treatments

The current study involved a randomised block design with a 2×2 factorial arrangement of treatments (Table 1 and Annex 1). The 62 experimental cows were blocked in groups of 4 cows based on breed (HF or Jer), the similarity of parity (first, second and higher parities), calving date, milk yield, fat and protein yield, FPCM production and body weight. Within blocks, cows were randomly assigned to one of the 4 treatments. The treatments consisted of two grazing systems (GrySyst) and two diet levels (DietLv) composed of rumen degradable protein. The differences in dietary level were created by supplementing the cows with 6 kg of concentrates with either an OEB+/- value of -50 g/kg or +50 g/kg DM according to DVE/OEB2007 protein evaluation system for dairy cows (Tamminga et al., 2007; Tamminga et al., 1994).

The grazing systems in the current study included kurzrasenweide (KR) (Steinberger et al., 2009) and strip grazing (SG) system. In each KR treatment group, 15 dairy cows were grazed continuously on a paddock during the whole season in which the sward height was maintained below 8 cm height. The herbage mass (kg DM/ha) in the whole paddock was managed such that the average total herbage accumulation (kg DM/ha/d) equals the average total quantity of herbage consumed by the grazing animals. A decrease or increase in herbage mass was counteracted by adjustment of the level of supplemental forages. Cows were allocated to a new strip of grasses daily and the level of supplemental forage was adjusted based on the pre- and post-grazing sward height. The objective was that all strips were sufficiently grazed down assessed based on the post grazing sward height. Strips with a pre-grazing sward height above 18 cm were removed from the rotation and used for a silage cut.

Table 1. Experimental design

Four experimental groups	Two grazing systems (GrSyst)	Lay-out	Walking distance to/from pastures	Two diet levels (DietLv)	Number of cows/Breed	Total number of cows
KR-H	KR	20 x 0.1 ha	700 m	H=OEB+	9 HF and 7 Jer	16
KR-L	KR	20 x 0.1 ha	700 m	L=OEB-	9 HF and 6 Jer	15
SG-H	SG	1 x 2.0 ha	400 m	H=OEB+	9 HF and 6 Jer	15
SG-L	SG	1 x 2.0 ha	700 m	L=OEB-	9 HF and 7 Jer	16
						62

2.3 The use of sensOor (AGIS) and Neck sensor (Nedap) in monitoring behaviour of cattle

SensOor (Agis Automatisering BV, Harmelen, the Netherlands) is a 3-dimensional accelerometer that can be attached to the identification ear tags of the cow. Based on the principle that cow's behaviour can be identified by the movements of the ear, the three-dimensional accelerometer continuously registers the movement of the cow's ear. The sensOor system can quantify ear temperature, ruminating, eating, and other activities i.e. active and resting in a close interval. The data collected are sent to the computer through a wireless connection, via a router installed in the farm. The raw data collected by the sensOor can be stored for a maximum period of 48 hours after the last recording. The proprietary model formulated, subsequently converts the raw data as percentages of cow's behaviour per hour or per day through the online web-based application (AmazingGrazing, 2017; Bikker et al., 2014; Kaptijn and Lantinga, 2016).

In the current experimental study, the behaviour of cows was recorded 24/7, when they are indoors and outdoors. The cows at DC Zegveld spent 8 hours outdoors and the remaining time indoor. The current study included behavioural data recorded by sensOor (AGIS, Harmelen) from May to October

2016; and the SmartTag neck (Nedap, Groenlo) sensor collected from June to October 2016 (Table 2). The combination of the two sensors enables to differentiate between grazing outdoors and eating roughages/concentrates indoor, and could provide more details in monitoring grazing behaviour of cows (Kaptijn and Lantinga, 2016). Generally, the use of sensOor contributes in monitoring cattle behaviour, fertility (heat detection), health and welfare traits in a close interval. This may contribute to reducing time researchers and farmers spend on monitoring individual cows, and hence reducing workload and increase efficiency and profitability in dairy farming (Bikker et al., 2014; Dolecheck et al., 2015).

Table 2. Information collected by the sensOor (AGIS) and Neck sensor (NEDAP)

Data collected	Equipment used
Standing and lying	Neck sensor (NEDAP)
Eating (eating roughage indoor and grazing outdoors)	Neck sensor (NEDAP) and sensOor (AGIS)
Rumination	sensOor (AGIS)

2.4 Animal performance and energy requirements

The energy requirements for lactation and maintenance ($NE_{L,\ required}$) for Jersey and HF cows were calculated by using the net energy method (Smit et al., 2005). The NE for lactation and maintenance calculations were based on the standard systems used in The Netherlands (Smit et al., 2005; Van Es, 1978) by using the following equation:

$NE_{L,required} = 6.9 \times [(42.4 \times BW^{0.75} + 442 \times FPCM) \times (1 + (FPCM - 15) \times 0.00165)]$ ---- *(Equation 1)*

Whereby: - BW = Average body weight of the cow in kg during the experimental period, and

- FPCM = Fat-Protein corrected milk measured in kg/day

FPCM= [(0.337 + 0.116 fat (%) + 0.06 protein (%)] x milk production (kg) --------- *(Equation 2)*

Since the dairy cows were grazing for 8 hours per day in the current study, an extra allowance of 10% of their maintenance requirements was assumed in the above equation. In the previous grazing experiments where cows were grazed for extended period, the extra maintenance requirements was 20% higher than for indoor-fed cows (Schlepers and Lantinga, 1985; Smit et al., 2005; Van Es, 1978). Animals were weighted on two consecutive days in every month, and the average of the two days was recorded, while the average FPCM per cow were calculated on weekly basis (Annex 1).

2.5 Data analysis

The primary data recorded by the computerised monitoring system for every 24 hours/day were introduced into Excel sheet, expressed as percentage activity of individual cow aggregated for each month. Furthermore, the data were coded and analysed by Genstat statistical software, to obtain the behavioural differences in activities of HF and JE cows. The special Generalised Linear Model (GLM) was used to predict means, standardised error and p-values for the main effects and pairwise comparison at a 95% level of significance. Furthermore, the pairwise comparison were carried out when there was a significant interaction between factors observed.

Since HF and JE cows were in the same environment at DC-Zegveld farm, the factorial analysis was used to analyse the behavioural differences between the breeds. The farm had 8 treatment groups, each group with 15+ cows (9 HF and 7 JE breeds) (Table 1); kept under 2 grazing systems (KR and SG); with two different diets (High (H=OAB+) and Low (L=OAB-) protein levels). Hence, based on the experimental factors a 2×2 factorial analysis was used, representing the (two breeds of cattle); two grazing systems (KR vs SG); and two diet levels (H and L).

Model equation:

Design: Grand mean + breed effect + grazing system effect + diet effect + interactions + error term

Y_{ijk} = Grand mean + Breed + GrSyst + DietLv + BreedxGrSyst + BreedxDietLv + GrSystXDietLv

$Y_{ijk} = \mu + B_i + G_j + D_k + Bi \times Gj + B_i \times D_k + G_j \times D_k + e_{ijk}$
Whereby:
Y_{ijk} = The response of the cow of breed *i* to treatment *j* (Grazing system) and *k* (diet level)
μ = Intercept
B_i = Breed effect (*i* = 1 or 2)
G_j = Grazing system effect (*j* = 1 to 2)
D_k = Diet effect (*k* = 1 to 2)
$Bi \times Gj$ = The interaction between breed x grazing system
$Bi \times D_k$ = Breed x Diet effect
$G_j \times D_k$ = Grazing x Diet effect Interaction
e_{ijk} = residual error term

Data analysis for the performance of cows

The primary data on BW and FPCM were introduced into Excel data sheet followed by calculating $NE_{L,required}$ by using the Net energy method (Equation 1), and analysed by the Statistical Package for Social Sciences (SPSS version 22). After checking for normality, the data were assumed to be normally distributed and subjected to the analysis of variance (ANOVA), whereby the mean differences between breeds in the experimental groups were computed.

3 Results

3.1. Eating/grazing behaviour of cows indoor and under pastures

Based on NEDAP output, Jersey cows spent longer time in eating/grazing as compared to HF cows (p-value ≤0.05) over the period of 24 hours throughout the experimental period (Table 3 and Figure 2a). However, there were no clear differences observed between the breeds indoors (Figure 2b). When cows were on pastures, Jersey cows spent longer time in grazing as compared to HF throughout the experimental period (Table 3c). Furthermore, the differences in time spent in eating/grazing were clearly shown under SG system in June and August, whereby the HF spent shorter time as compared to Jersey cows (Figure 2b, 2c).

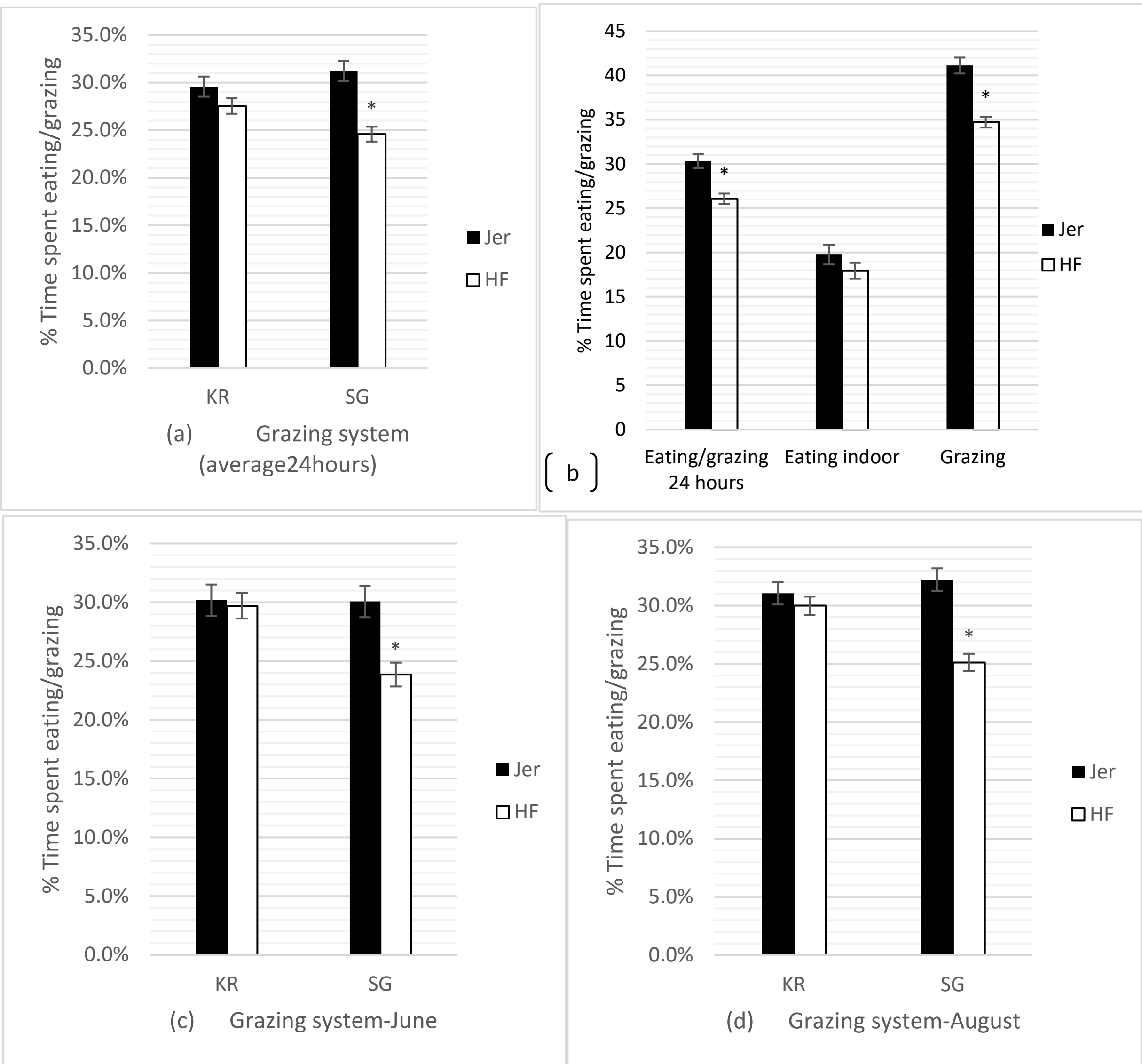

Figure 2. Percentage time (Mean ± SEM) spent on eating/grazing over 24 hours (NEDAP)
* Significant differences between breeds (p≤0.05)

Table 3. Time spent on grazing/eating (NEDAP sensor)

Activity	Month	Prediction and s.e (%)						*Level of significance (P-value)*					
		Grazing System		Diet level		Breed							
		KR	SG	OEB+	OEB-	Jer	HF	GrSyst	DietLv	Breed	GrSystXDietLv	GrSystXBreed	DietLvXBreed
	June	30.23	26.66	27.55	29.35	30.12	26.78	**0.01**	NS	**0.01**	**0.02**	**0.02**	NS
	s.e	0.9	0.9	0.9	0.9	1.0	0.8						
	July	29.17	28.07	27.92	29.33	31.32	25.93	NS	NS	**0.00**	NS	NS	NS
	s.e	0.7	0.6	0.6	0.7	0.7	0.6						
(a) Eating/grazing (NEDAP) 24 hours	Aug	30.83	28.36	28.63	30.55	31.63	27.55	**0.01**	**0.05**	**0.00**	NS	**0.00**	NS
	s.e	0.7	0.7	0.7	0.7	0.8	0.6						
	Sep	28.68	27.67	27.74	28.90	30.95	25.69	NS	NS	**0.00**	**0.03**	NS	NS
	s.e	0.9	0.9	0.9	0.9	1.0	0.8						
	Oct	26.78	27.73	26.11	28.40	30.13	24.39	NS	NS	**0.00**	NS	NS	NS
	s.e	0.8	0.8	0.8	0.8	0.9	0.8						
	Av_24	28.81	27.58	27.26	29.13	30.33	26.07	NS	NS	**0.00**	NS	**0.02**	NS
	s.e	0.7	0.7	0.7	0.7	0.8	0.6						
	June	14.51	16.79	14.92	16.38	17.19	14.11	**0.05**	NS	**0.01**	NS	NS	NS
	s.e	0.8	0.8	0.8	0.8	0.9	0.7						
	July	17.81	20.18	18.50	19.49	20.59	17.40	NS	NS	**0.03**	NS	NS	NS
	s.e	1.0	1.0	1.0	1.0	1.9	0.9						
(b) Eating indoor (NEDAP)	Aug	14.08	17.71	15.12	16.66	16.87	14.92	**0.01**	NS	NS	NS	**0.04**	NS
	s.e	0.9	1.0	0.9	1.0	1.0	0.8						
	Sep	19.57	22.28	20.62	21.23	22.05	19.80	NS	NS	NS	NS	**0.04**	NS
	s.e	1.2	1.3	1.2	1.2	1.2	1.2						
	Oct	23.59	25.15	23.48	25.26	25.28	23.46	NS	NS	NS	NS	**0.01**	NS
	s.e	1.4	1.4	1.4	1.4	1.5	1.2						
	Av_24	17.53	20.17	18.14	19.55	19.76	17.94	NS	NS	NS	NS	**0.01**	NS
	s.e	1.0	1.0	1.0	1.0	1.1	0.9						
	June	43.71	40.43	40.41	43.73	43.84	40.31	NS	NS	NS	**0.00**	**0.04**	NS
	s.e	1.3	1.3	1.3	1.3	1.4	1.2						
	July	39.00	39.24	38.16	40.07	42.83	35.40	NS	**0.05**	**0.00**	NS	NS	NS
	s.e	0.7	0.7	0.7	0.7	0.8	0.6						
(c) Grazing pastures (NEDAP)	Aug	45.55	39.34	41.30	43.59	45.49	39.40	**0.00**	**0.04**	**0.00**	NS	**0.00**	**0.04**
	s.e	0.8	0.8	0.8	0.8	0.9	0.7						
	Sep	36.27	33.26	33.77	35.75	38.65	30.87	**0.03**	NS	**0.00**	**0.01**	NS	**0.00**
	s.e	1.0	1.0	1.0	1.0	1.1	0.9						
	Oct	29.74	35.80	31.95	33.59	37.87	27.67	**0.00**	NS	**0.00**	NS	**0.04**	**0.03**
	s.e	0.8	0.9	0.9	0.9	1.1	0.8						
	Av_24	38.56	37.30	36.64	39.21	41.13	34.73	NS	**0.01**	**0.00**	**0.05**	NS	NS
	s.e	0.7	0.7	0.7	0.7	0.9	0.6						

NS – Not significant (p-value ≥0.05); In bold – significant factors and interactions; s.e=standard error; Av_24=Average
GrSyst=Grazing system; KR= kurzBreeden; SG=strip grazing; OEB+=High protein DietLv; OEB-=low protein diet; Jer=Jersey; HF=Holstein Friesian

3.2. Influence of grazing system on grazing behaviour

Generally, based on the NEDAP output, Jersey cows spent longer time in grazing (p-value ≤0.05) as compared to HF when they were on pastures (Table 3c). However, the time spent on grazing in June, August, September and October were mainly due to the interaction between breed, grazing system and the diet level. During the grazing period in June and August, the differences in time spent on grazing was observed under SG grazing system, where by HF spent short time as compared to Jersey cows (Figure 3a, b). On the other hand, when cows were on pastures in September and October, HF spent short time in grazing as compared to Jersey cows in both KR and SG (Figure 3c, d).

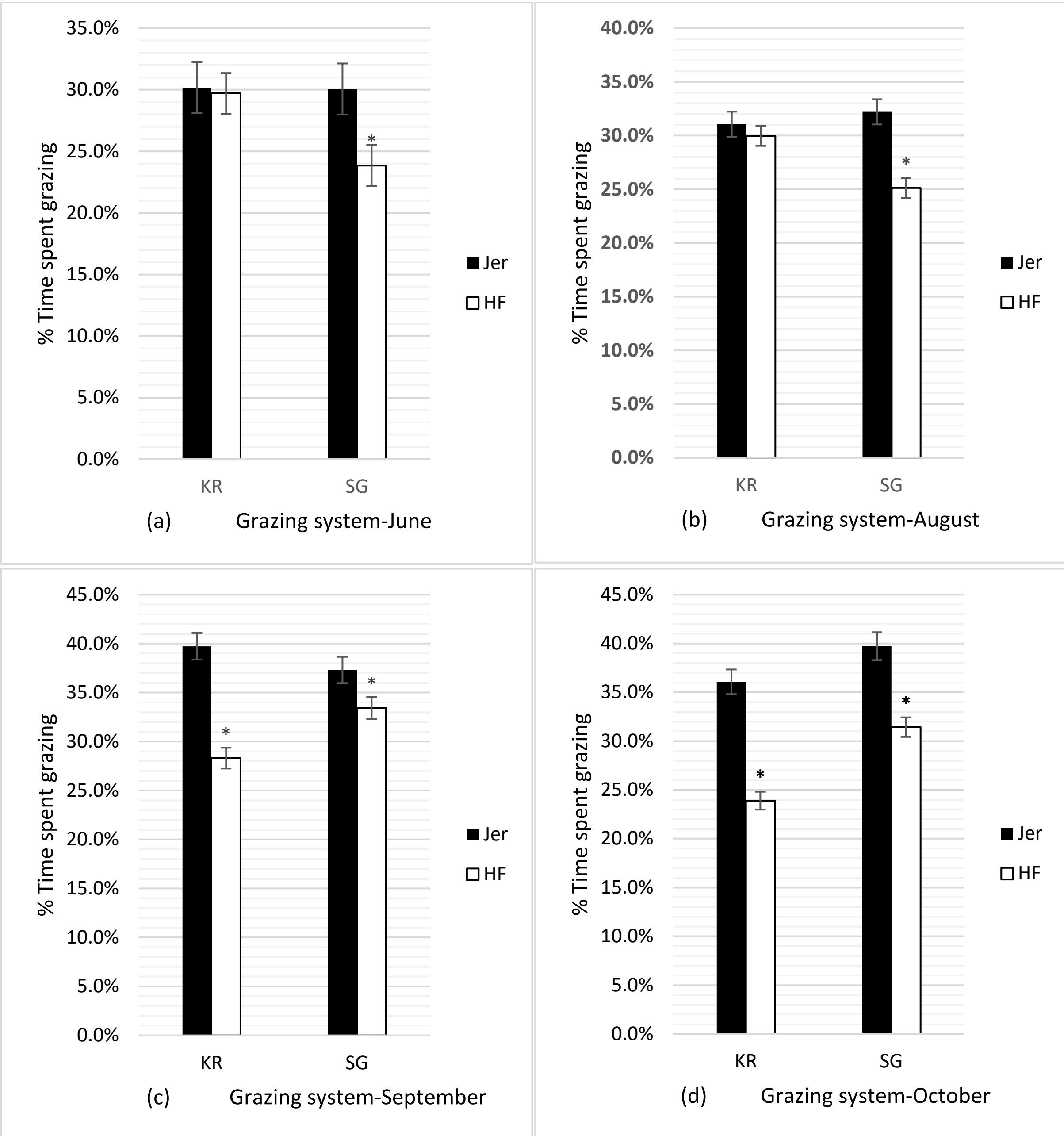

Figure 3. Effect of the grazing system on time spent in grazing between breeds
(Mean ± SEM), * Significant differences between breeds (p≤0.05)

3.3. Effects of changing diet level (protein level) grazing behaviour

Based on the output of the NEDAP sensor, the effects of changing diet level were mostly observed when cows were on pastures throughout the experimental period (Table 3). During the grazing period in August, September and October, Jersey cows were not affected by changing the diet levels, while the HF cows spent longer time in grazing when supplied with low protein diet (Figure 4).

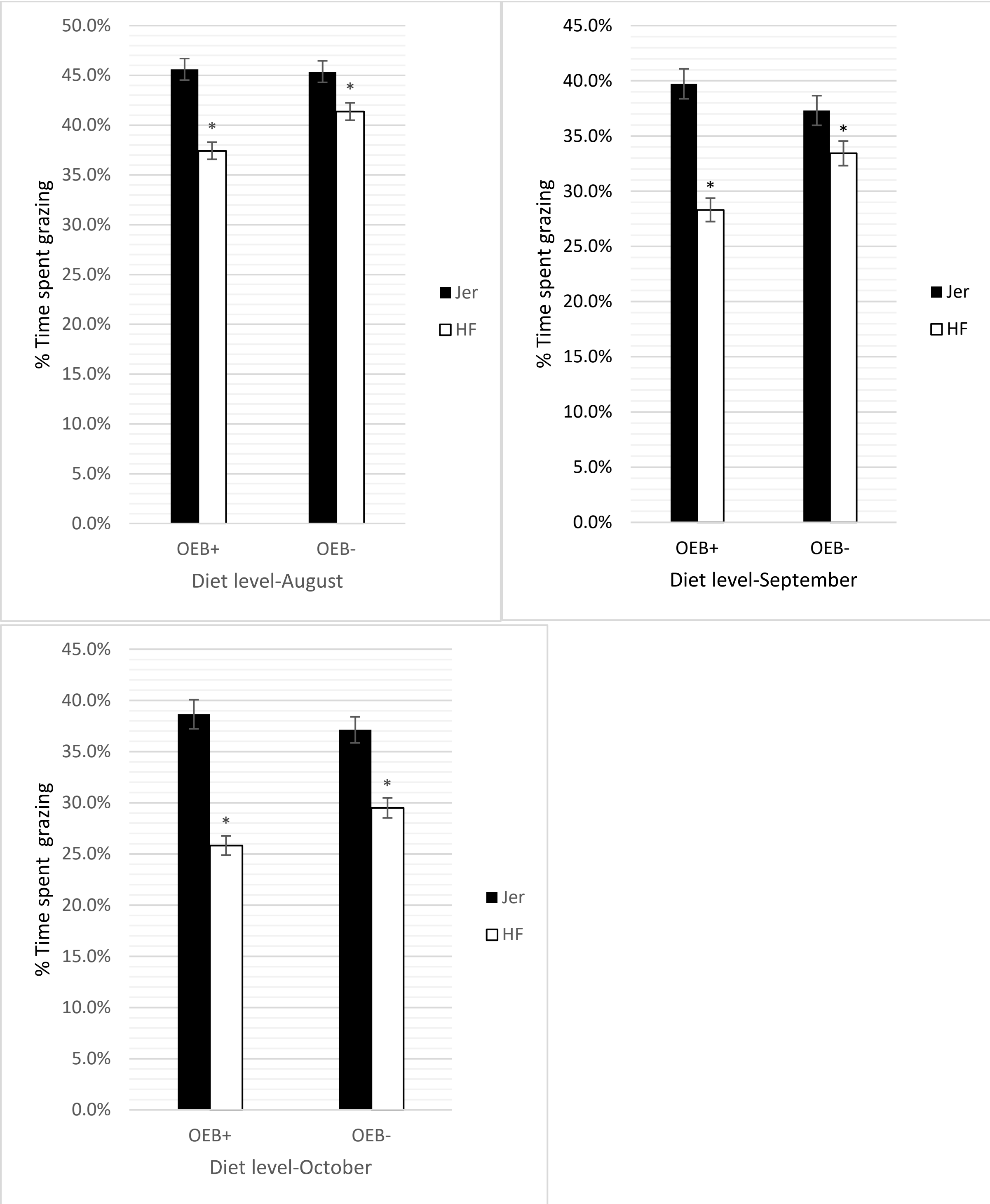

Figure 4. Effects of changing diet level on time spent on grazing
(Mean ± SEM), * Significant differences between breeds (p≤0.05)

3.4. Differences in rumination behaviour

Based on the sensOor output HF spent longer time in ruminating (p-value≤0.05) as compared to Jersey cows over the period of 24 hours (Table 4). However, the average time spent t in ruminating was significant higher when cows were on pastures (Figure 5). Also, during the grazing period in October, the effect of changing diet level on time spent on rumination were observed, whereby HF spent longer time in rumination as compared to Jersey cows when supplied with low degradable protein (Figure 6).

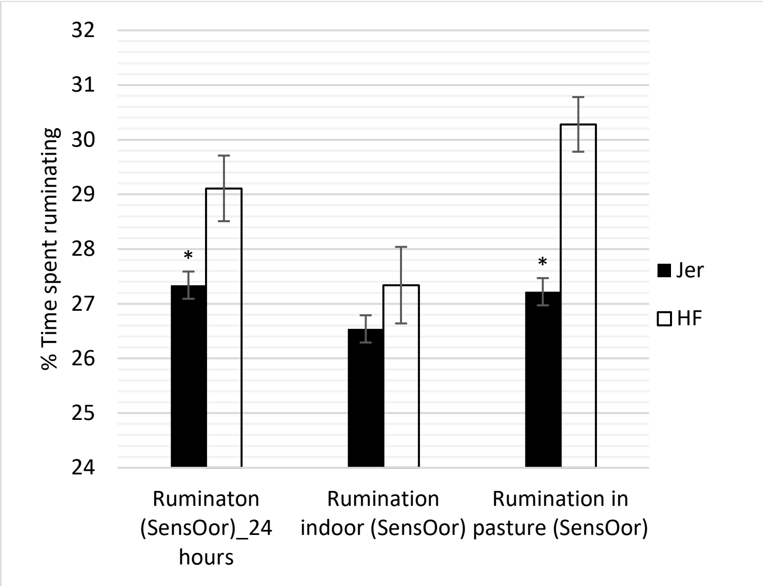

Figure 5. Rumination behaviour indoor and outdoor
(Mean ± SEM), * Significant differences between breeds (p≤0.05)

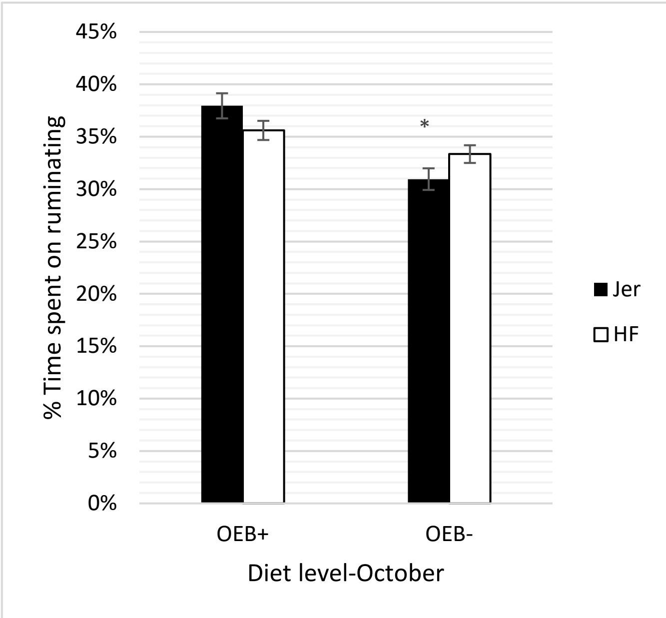

Figure 6. Effects of changing diet level on percentage time spent on ruminating in October

(Mean ± SEM), * Significant differences between breeds (p≤0.05)

When cows were indoor, the differences in time spent on rumination was observed in May and June (p-value≤0.05), whereby HF spent longer time on rumination as compared to Jersey cows (Table 4b). On the other hand, when cows were on pastures HF spent longer time in rumination as compared to Jersey cows throughout the experimental period (Table 4c). However, when cows were on pastures in May, HF spent longer time in rumination under SG as compared to Jersey cows, while there were no significant differences observed between breeds under KR system (Figure 7).

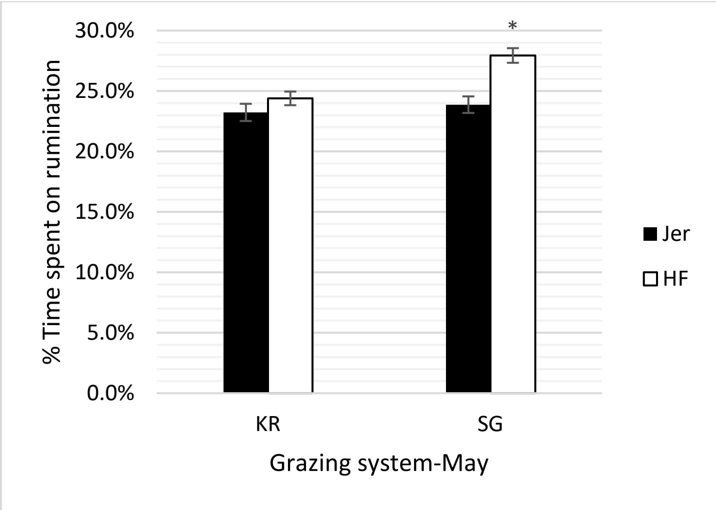

Figure 7. Effects of changing diet level on percentage time spent on rumination in May

(Mean ± SEM), * Significant differences between breeds (p≤0.05)

Table 4. Rumination activities of Jersey and Holstein-Friesian cows (sensOor)

Activity	Month	Prediction and s.e (%)						*Level of significance (P-value)*					
		GrSyst		DietLv		Breed							
		KR	SG	OEB+	OEB-	Jer	HF	GrSyst	DietLv	Breed	GrSystXDietLv	GrSystXBreed	DietLvXBreed
a) Rumination (SensOor) 24 hours	May	26.57	27.35	28.04	25.88	24.90	29.02	NS	**0.00**	**0.00**	NS	NS	NS
	s.e	0.5	0.5	0.5	0.5	0.6	0.5						
	June	26.33	27.75	28.35	25.71	25.67	28.41	NS	**0.00**	**0.00**	NS	NS	NS
	s.e	0.6	0.6	0.6	0.6	0.7	0.6						
	July	26.26	28.96	29.58	25.64	26.76	28.46	**0.03**	**0.00**	NS	NS	NS	NS
	s.e	0.8	0.9	0.9	0.8	1.0	0.8						
	Aug	24.46	26.32	27.03	23.76	24.37	26.42	**0.04**	**0.00**	**0.03**	NS	NS	NS
	s.e	0.6	0.7	0.7	0.6	0.7	0.6						
	Sep	25.82	27.51	28.44	24.89	25.33	28.00	NS	**0.00**	**0.00**	NS	NS	NS
	s.e	0.6	0.7	0.7	0.6	0.7	0.6						
	Oct	32.19	36.64	36.45	32.37	34.30	34.52	**0.00**	**0.00**	NS	NS	NS	**0.02**
	s.e	0.7	0.8	0.8	0.6	0.8	0.7						
	Av_24	27.10	29.34	30.02	26.43	27.34	29.11	**0.01**	**0.00**	NS	NS	NS	NS
	s.e	0.6	0.7	0.7	0.6	0.7	0.6						
b) Rumination indoor (SensOor)	May	30.02	28.93	29.78	29.18	26.54	32.41	NS	NS	**0.00**	NS	NS	NS
	s.e	0.8	0.8	0.9	0.8	0.9	0.8						
	June	26.36	27.07	27.99	25.44	25.18	28.25	NS	**0.02**	**0.01**	NS	NS	NS
	s.e	0.4	0.7	0.8	0.7	0.8	0.7						
	July	22.60	25.71	26.28	22.03	23.78	24.53	**0.03**	**0.00**	NS	NS	NS	NS
	s.e	1.0	1.0	1.0	1.0	1.1	0.9						
	Aug	24.33	24.71	26.09	22.95	24.22	24.82	NS	**0.01**	NS	NS	NS	NS
	s.e	0.8	0.9	0.9	0.8	0.9	0.8						

	Sep	22.23	25.08	25.55	21.76	23.43	23.88	**0.02**	**0.00**	NS	NS	NS	NS
	s.e	0.8	0.9	0.9	0.8	1.0	0.8						
	Oct	25.89	36.13	33.18	28.85	32.22	29.80	**0.00**	**0.00**	NS	NS	NS	NS
	s.e	0.9	1.0	1.0	0.90	1.1	0.8						
	Av_24	25.45	28.43	28.69	25.19	26.54	27.34	**0.01**	**0.00**	NS	NS	NS	NS
	s.e	0.7	0.8	0.8	0.7	0.9	0.7						
c) Rumination in pasture (SensOor)	May	23.64	26.02	26.58	23.09	23.51	26.15	**0.00**	**0.00**	**0.00**	NS	**0.04**	NS
	s.e	0.5	0.5	0.5	0.5	0.5	0.4						
	June	26.57	27.20	28.14	25.63	25.53	28.25	NS	**0.00**	**0.00**	NS	NS	NS
	s.e	0.6	0.6	0.6	0.6	0.6	0.5						
	July	29.50	31.05	31.96	28.59	28.86	31.89	NS	**0.00**	**0.03**	NS	NS	NS
	s.e	0.9	0.9	0.9	0.8	1.0	0.8						
	Aug	24.66	28.03	27.98	24.70	24.60	28.08	**0.00**	**0.00**	**0.00**	NS	NS	NS
	s.e	0.6	0.6	0.6	0.6	0.7	0.6						
	Sep	28.91	30.00	31.12	27.79	27.11	31.80	NS	**0.00**	**0.03**	NS	NS	NS
	s.e	0.7	0.7	0.7	0.6	0.7	0.6						
	Oct	37.40	31.64	35.25	33.70	32.64	36.40	**0.00**	NS	**0.01**	**0.03**	NS	NS
	s.e	0.9	1.0	1.0	0.9	1.0	0.8						
	Av_24	28.54	28.95	30.34	27.15	27.22	30.28	NS	**0.00**	**0.00**	NS	NS	NS
	s.e	0.6	0.6	0.6	0.6	0.7	0.5						

NS – Not significant (p-value ≥0.05); In bold – significant factors and interactions; s.e=standard error; Av_24=Average
GrSyst=Grazing system; KR= kurzBreeden; SG=strip grazing; OEB+=High protein diet; OEB-=low protein diet; Jer=Jersey; HF=Holstein Friesian

3.5. Time spent in standing by Jersey and Holstein-Friesian cows

Based on the NEDAP output, HF spent shorter time in standing as compared to HF (p-value≤0.05) over the period of 24 hours in both grazing systems (Table 5 and Figure 8a). However, there were no significant differences in time spent on standing when both breeds were indoor (Figure 8a), except for September whereby Jersey cows spent longer time in standing as compared to HF (p-value≤0.05) as seen in Table 5. On the other hand, when cows were on pastures in October the differences in the time spend grazing was significantly different within the HF cows, where they spent longer time in SG system (Figure 8b).

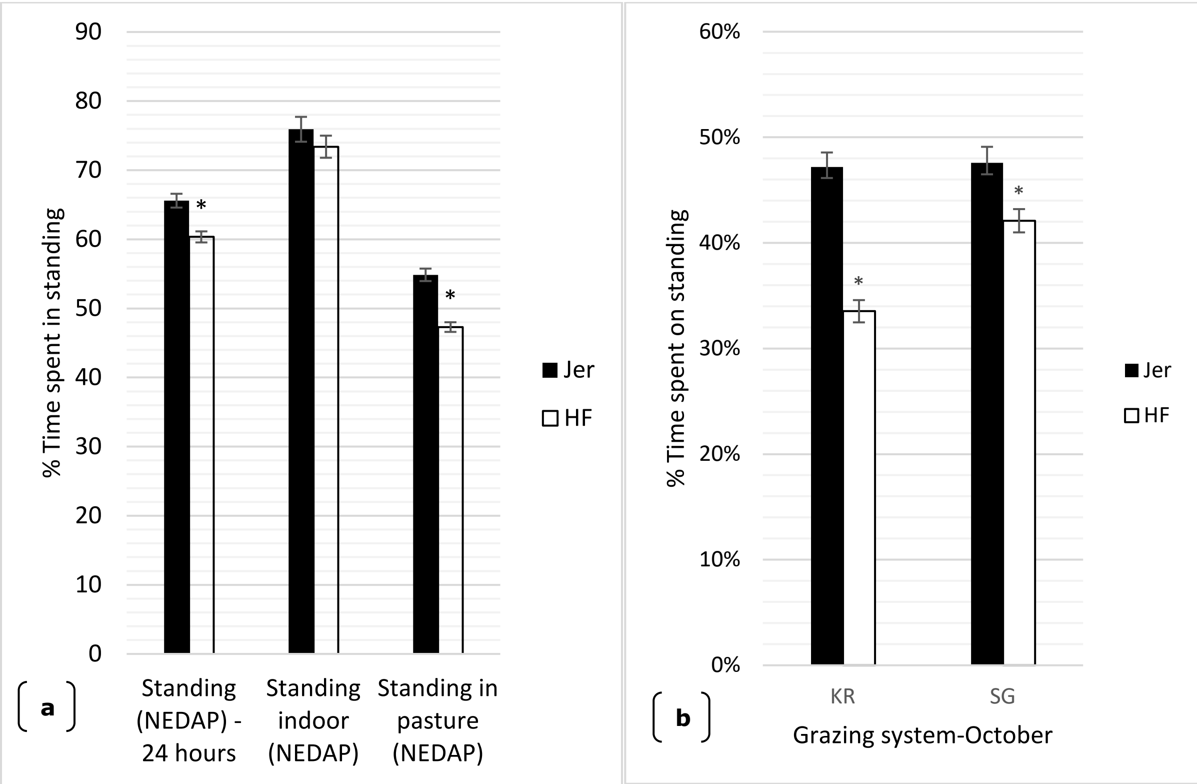

Figure 8. The percentage time spent in standing for HF and Jersey cows (NEDAP).
(Mean ± SEM), * Significant differences between breeds (p≤0.05)

Table 5. Standing time for Jersey and Holstein-Friesian cows (NEDAP)

Activity	Month	Prediction and s.e (%) GrSyst		DietLv		Breed		Level of significance (P-value)					
		KR	SG	OEB+	OEB-	Jer	HF	GrSyst	DietLv	Breed	GrSystXDietLv	GrSystXBreed	DietLvXBreed
(A) Standing (NEDAP) 24 hours	June	64.92	64.42	64.06	65.28	66.04	63.30	NS	NS	**0.04**	NS	NS	NS
	s.e	0.9	0.9	0.9	0.9	1.0	0.8						
	July	62.57	61.40	61.16	62.81	64.05	59.52	NS	NS	**0.00**	NS	NS	NS
	s.e	0.9	0.9	0.9	0.9	1.0	0.8						
	Aug	63.53	62.35	61.96	63.92	65.60	60.28	NS	NS	**0.00**	NS	NS	NS
	s.e	1.0	1.0	1.0	1.0	1.0	0.9						
	Sep	63.54	61.24	60.59	63.88	66.30	58.48	NS	**0.04**	**0.00**	NS	NS	NS
	s.e	1.0	1.0	1.1	1.0	1.1	1.0						
	Oct	62.30	63.20	61.38	64.13	65.18	60.02	NS	NS	**0.00**	NS	NS	NS
	s.e	1.0	1.0	1.1	1.1	1.1	1.0						
	Av_24	63.41	62.52	61.93	64.00	65.59	60.35	NS	NS	**0.00**	NS	NS	NS
	s.e	0.9	0.9	0.9	0.9	1.0	0.8						
(B) Standing indoor (NEDAP)	June	66.47	64.95	65.08	66.33	66.28	65.14	NS	NS	NS	NS	NS	NS
	s.e	1.6	1.6	1.6	1.6	1.8	1.5						
	July	76.82	70.61	73.10	74.34	74.70	72.73	**0.01**	NS	NS	NS	NS	NS
	s.e	1.6	1.8	1.7	1.7	1.8	1.6						
	Aug	72.81	74.24	73.21	73.85	75.53	71.82	NS	NS	NS	NS	NS	NS
	s.e	1.8	1.8	1.8	1.8	1.9	1.7						
	Sep	83.49	79.97	80.56	82.90	84.20	79.26	NS	NS	**0.05**	NS	NS	NS
	s.e	1.6	1.7	1.7	1.6	1.7	1.6						
	Oct	87.62	69.93	77.11	80.44	78.72	78.83	**0.00**	NS	NS	NS	NS	NS
	s.e	1.5	2.0	1.8	1.7	2.0	1.6						
	Av_24	77.49	71.83	73.89	75.46	75.92	73.40	**0.01**	NS	NS	NS	NS	NS
	s.e	1.5	1.7	1.6	1.6	1.8	1.6						
(C) Standing in pasture (NEDAP)	June	63.00	65.52	63.33	65.18	66.46	62.05	NS	NS	**0.00**	**0.00**	NS	NS
	s.e	0.9	0.9	0.9	0.9	1.0	0.9						
	July	49.97	50.93	49.37	51.53	53.42	47.49	NS	**0.03**	**0.00**	NS	NS	NS
	s.e	0.7	0.7	0.7	0.7	0.8	0.6						
	Aug	55.40	50.02	51.21	54.21	56.08	49.34	**0.00**	**0.01**	**0.00**	NS	NS	NS
	s.e	0.8	0.9	0.8	0.9	0.9	0.8						
	Sep	46.82	43.15	43.26	46.71	50.20	39.77	**0.01**	**0.02**	**0.00**	NS	NS	NS
	s.e	1.0	1.0	1.0	1.0	1.1	0.9						
	Oct	39.97	45.50	41.27	44.20	47.65	37.82	**0.00**	**0.03**	**0.00**	NS	**0.00**	NS
	s.e	0.9	1.0	1.0	0.9	1.1	0.8						
	Av_24	51.05	51.11	49.70	52.47	54.86	47.30	NS	**0.02**	**0.00**	NS	NS	NS
	s.e	0.8	0.8	0.8	0.8	0.9	0.7						

NS – Not significant (p-value ≥0.05); In bold – significant factors and interactions; s.e=standard error; Av_24=Average
GrSyst=Grazing system; KR= kurzBreeden; SG=strip grazing; OEB+=High protein diet; OEB-=low protein diet; Jer=Jersey; HF=Holstein Friesian

3.6. Comparison of the efficiency of sensOor and NEDAP output

Based on the average time spent on eating/grazing NEDAP shows significant differences between the breed (p-value≤0.05) during the experiment, while the sensOor output shows no significant differences between Jersey and HF cows over 24 hours (Figure 9a). When cows were indoor, sensOor output shows that there were significant differences between the breeds in May, September and October (Table 6b), whereby Jersey cows spent longer time in eating as compared to HF. Furthermore, when cows were indoor both sensOor and NEDAP shows no significance differences in time spent eating between the breeds (Figure 9b). However, when cows when indoor, sensOor overestimate the time spent in eating for both breeds as compared to NEDAP (Figure 9b). On the other hand, when cows were on pastures, NEDAP shows that there were significant differences in time spent in eating between the breeds (Figure 9c). However, the differences on the output of NEDAP and sensOor was slightly lower under pasture condition.

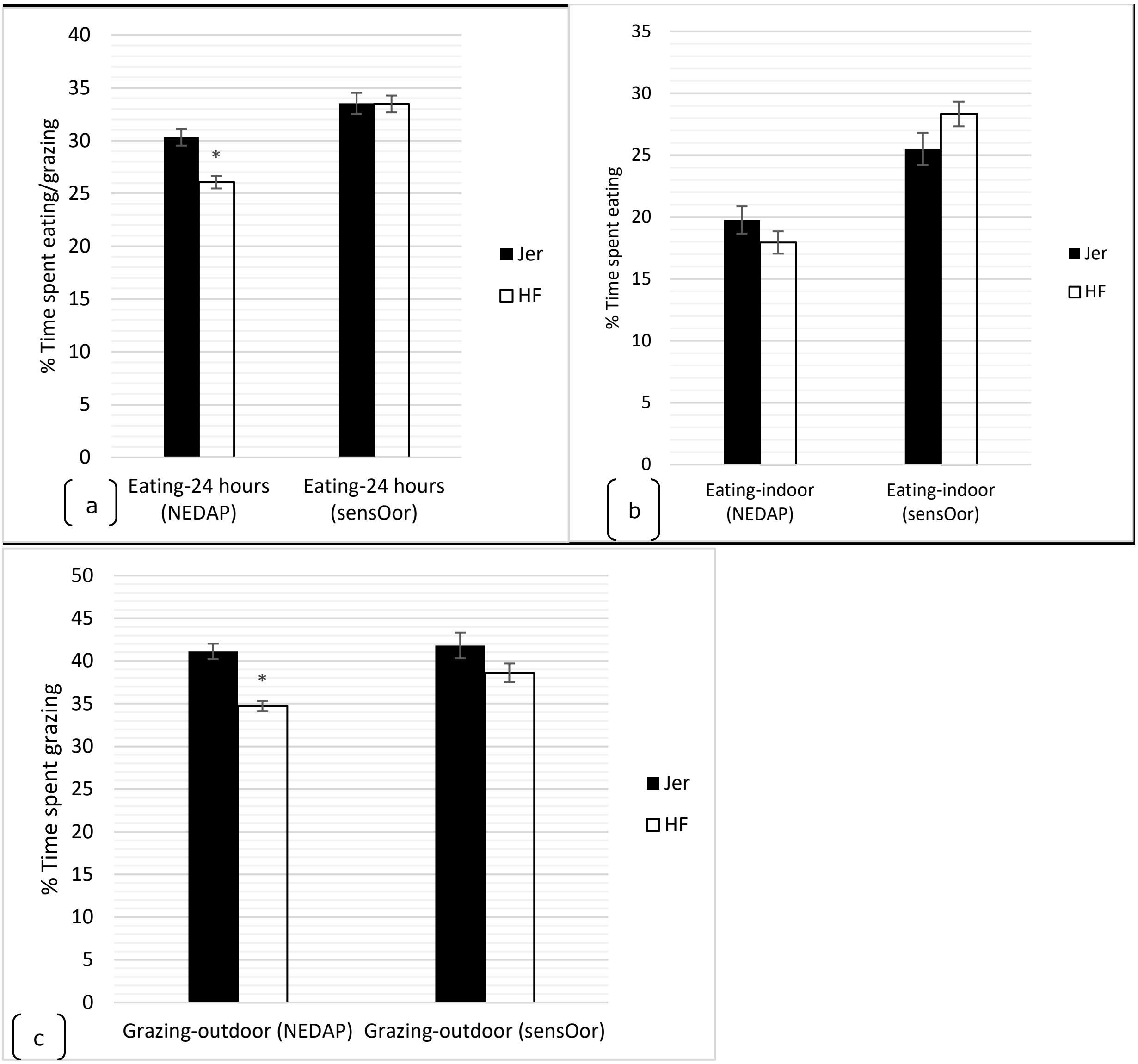

Figure 9. Comparison of the NEDAP and sensOor output
(Mean ± SEM), * Significant differences between breeds (p≤0.05)

Table 6. Grazing/eating behaviour of Jersey and Holstein-Friesian cows (sensOor)

Activity	Month	Prediction and s.e (%)						Level of significance (P-value)					
		GrSyst		*DietLv level*		*Breed*							
Activity	**Month**	KR	SG	OEB+	OEB-	Jer	HF	GrSyst	DietLv	Breed	GrSystXDietLv	GrSystXBreed	DietLvXBreed
(A) Eating/grazing 24 hours (SensOor)	**May**	27.44	31.55	29.47	29.52	30.18	28.81	**0.01**	NS	NS	NS	NS	NS
	s.e	1.0	1.0	1.0	1.0	1.1	0.9						
	June	33.05	33.75	32.60	34.17	33.59	33.18	NS	NS	NS	**0.03**	NS	NS
	s.e	1.0	1.0	1.0	1.0	1.1	0.9						
	July	36.18	35.69	33.45	38.42	35.83	36.04	NS	**0.00**	NS	NS	NS	NS
	s.e	0.9	0.9	0.9	0.9	1.0	0.8						
	Aug	34.47	33.77	33.02	35.22	34.57	33.67	NS	NS	NS	NS	NS	NS
	s.e	1.0	1.0	1.0	1.0	1.1	0.9						
	Sep	35.42	34.19	33.20	36.41	34.92	34.69	NS	**0.03**	NS	**0.04**	NS	NS
	s.e	1.0	0.9	1.0	0.9	1.1	0.8						
	Oct	36.20	32.44	31.95	36.56	34.64	33.87	**0.01**	**0.00**	NS	NS	NS	NS
	s.e	0.9	1.0	1.0	0.9	1.1	0.8						
	Av_24	33.69	33.31	32.35	34.64	33.53	33.47	NS	NS	NS	NS	NS	NS
	s.e	0.8	0.9	0.9	0.8	1.0	0.8						
(B) Eating indoor (SensOor)	**May**	16.14	14.78	14.02	16.91	17.29	13.64	NS	**0.05**	**0.01**	NS	NS	NS
	s.e	1.0	1.0	1.0	1.0	1.2	0.9						
	June	23.49	22.43	20.35	25.57	23.14	22.29	NS	**0.00**	NS	NS	NS	NS
	s.e	1.1	1.1	1.1	1.1	1.2	1.0						
	July	32.27	31.09	27.46	35.90	30.09	33.27	NS	**0.00**	NS	NS	NS	NS
	s.e	1.3	1.3	1.3	1.3	1.5	1.2						
	Aug	24.52	26.99	23.31	28.20	24.30	27.21	NS	**0.03**	NS	NS	NS	NS
	s.e	1.2	1.3	1.2	1.3	1.4	1.1						
	Sep	32.94	32.48	29.81	35.60	30.30	35.12	NS	**0.00**	**0.01**	NS	NS	NS
	s.e	1.3	1.4	1.3	1.3	1.5	1.2						

	Oct	40.13	31.25	32.81	38.57	33.25	38.14	**0.00**	**0.03**	**0.02**	NS	**0.05**	NS
	s.e	1.4	1.4	1.4	1.3	1.5	1.2						
	Av_24	28.11	25.72	24.23	29.60	25.51	28.32	NS	**0.00**	NS	NS	NS	NS
	s.e	1.1	1.2	1.1	1.1	1.3	1.0						
(C) Grazing outdoor (SensOor)	**May**	37.05	45.78	42.56	40.26	41.12	41.70	**0.00**	NS	NS	NS	NS	NS
	s.e	2.0	2.1	2.1	2.0	2.3	1.9						
	June	41.05	46.38	44.71	42.72	44.03	43.40	**0.02**	NS	NS	**0.02**	NS	NS
	s.e	1.6	1.6	1.6	1.6	1.8	1.4						
	July	39.64	43.06	40.76	41.93	42.81	39.88	**0.05**	NS	NS	NS	NS	NS
	s.e	1.2	1.3	1.3	1.3	1.4	1.1						
	Aug	43.20	40.60	42.17	41.66	44.20	39.63	NS	NS	NS	**0.01**	NS	NS
	s.e	1.2	1.2	1.2	1.2	1.4	1.1						
	Sep	37.42	35.61	35.99	37.04	38.85	34.18	NS	NS	**0.01**	**0.04**	NS	**0.05**
	s.e	1.1	1.1	1.2	1.1	1.3	1.0						
	Oct	32.77	37.88	34.57	36.08	39.15	31.50	**0.00**	NS	NS	**0.00**	NS	NS
	s.e	1.0	1.2	1.1	1.1	1.3	1.0						
	Av_24	38.51	41.90	40.69	39.72	41.81	38.60	NS	NS	NS	NS	NS	NS
	s.e	1.2	1.3	1.3	1.2	1.5	1.1						

NS – Not significant (p-value ≥0.05); In bold – significant factors and interactions; s.e=standard error; Av_24=Average
GrSyst=Grazing system; KR= kurzBreeden; SG=strip grazing; OEB+=High protein diet; OEB-=low protein diet; Jer=Jersey; HF=Holstein Friesian

3.7. Performance evaluation and energy requirements of cows

The mean body weight (BW), fat-and protein-corrected milk (FPCM) and daily net energy for milk production and maintenance ($NE_{L,required}$) was significant lower for Jersey as compared to HF cows (p-value ≤0.05) in all experimental groups, throughout the experimental period (Table 7 and Figure 9). Also, when looking on the "within breed effect", we observed that there are no significant effects of the grazing systems and changing the diet level observed on the BW, FPCM and $NE_{L,\ required}$ for both Jersey and HF cows (Figure 9).

Table 7. BW, FPCM and NEL,requirements for Jersey and HF cows

	Experimental group (Mean + SE)								***p-value***
	KR-H		KR-L		SG-H		SG-L		
	Jersey	HF	Jersey	HF	Jersey	HF	Jersey	HF	
BW, kg	393.5 (13.3)	586.4 (25.2)	370.8 (13.2)	565.2 (25.5)	382.9 (18.2)	584.8 (16.0)	393.2 (14.0)	554.3 (12.5)	**0.00**
FPCM, kg/day	20.6 (1.2)	24.2 (1.4)	19.3 (1.7)	23.1 (1.1)	20.6 (1.1)	25.8 (1.0)	17.9 (1.1)	23.6 (0.8)	**0.00**
$NE_{L,required}$ (MJ/day)	89.4 (4.3)	110.5 (4.6)	84.3 (6.0)	105.8 (4.5)	89.1 (4.0)	115.4 (3.4)	80.8 (3.5)	106.9 (2.9)	**0.00**

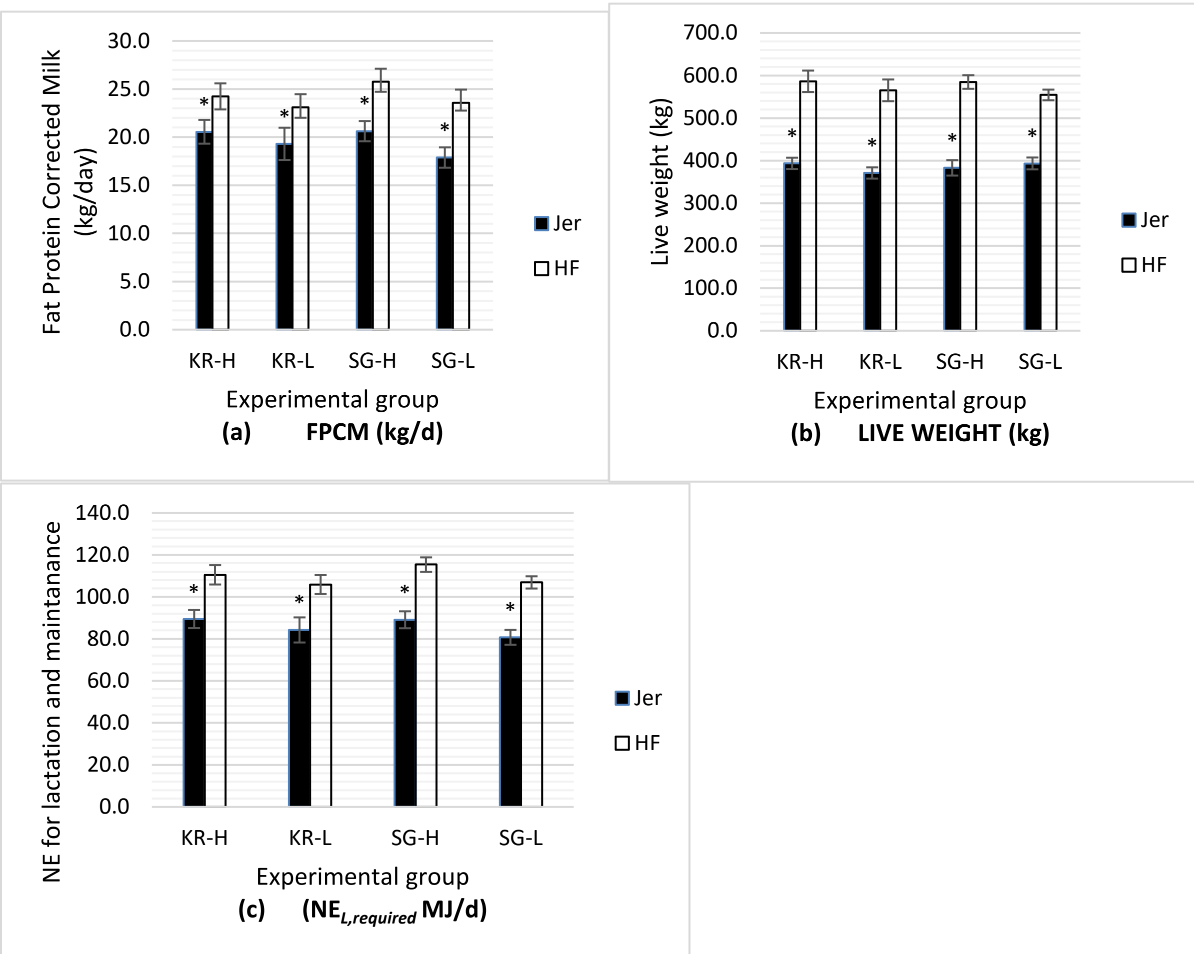

Figure 10. Comparison of Jersey and HF cow's BW, FPCM and NE_L,requirements
(Mean ± SEM), * Significant differences between breeds (p≤0.05)

4 Discussion

The main objective of the current study was to investigate whether the differences in grazing behaviour exist between Jersey and HF cows under Netherlands pasture-based management systems. We have examined the differences in behavioural activities indoor and under pasture condition by using two different types of sensors i.e. sensOor and NEDAP. Furthermore, to get more insights on the behavioural differences of Jersey and HF cows, the current study included two grazing systems (KR and SG) and two levels of degradable proteins (OEB+ and OEB-). Therefore, in the current study, we hypothesised that Jersey cows perform better under grazing condition as compared to the HF cows and also, supplementation with low degradable protein might have increased the time spent in grazing as compared to high degradable protein. We discussed various observations of the present study in the following sections.

Although Jersey cows have been reported as a suitable breed under predominantly pasture-based diet by many authors in the previous studies (Buckley et al., 2005; Prendiville et al., 2010), to date, there are few studies reported on the comparison of the behavioural differences of Jersey and HF cows under pasture-based production systems. The current study examines the application of sensOor and NEDAP in monitoring behaviour of cows indoors and outdoors. These sensors could potentially be used as an alternative method to the physical observation of dairy herd and increasing efficiency in monitoring production, reproduction, health and welfare traits in a close interval.

The efficiency of sensOor and NEDAP in monitoring behavioural activities

In the current study, the behavioural activities of cows i.e. time spent on eating/grazing and standing when indoor and outdoor were clearly shown from the NEDAP output. On the other hand, the sensOor output shows no significant differences in behavioural activities between the breeds in most cases during the experimental period. However, the sensOor output shows significant differences in time spent on rumination between the two breeds. Recently, NEDAP sensor has been successfully validated and used to record grazing behaviour of HF cows under pasture condition (Van Reenen et al., 2016). On the other hand, Kaptijn and Lantinga (2016) validated the sensOor under grazing condition, where they observed no significant differences between grazing outdoors and eating roughages/concentrates indoor from the sensOor output, which was also observed in the current study. Therefore, the discussions section on the time spent on eating/grazing and standing will rely on the NEDAP results, while the section on the time spent in rumination will be discussed based on the sensOor results.

Behavioural activities of Jersey and HF indoor and on pastures

Generally, Jersey cows spent longer time in eating/grazing as compared to HF throughout the experimental period, which is associated with the long time spent in standing. The ability of Jersey cows to stand for a long time is associated with their smaller physical size and less energy requirements as compared to HF observed in the current study, which was also observed by (Prendiville, 2009). Previous studies reported that Jersey cows have greater feed intake capacity mainly due to their large digestive tract per unit live weight as compared to HF (Goddard and Grainger, 2004; Prendiville, 2009). Similar studies reported that the digestive capacity (the total weight of gastrointestinal tract per LW) of HF is only 88-95% of the Jersey cows (Smith and Baldwin, 1974), which is associated with the large capacity of the Jersey cows to consume a large amount of roughages per kg body weight. Furthermore, Prendville et al. (2009) suggested that Jersey cows have higher intake capacity per unit of BW, where they consumed an extra 5.1% DM per Kg metabolic BW compared to HF.

On the other hand, Bargo et al, (2002) and McCarthy et al, (2007b) emphasised that the high producing HF cows have more biting rates associated with the higher production and maintenance requirements. In addition, Jersey cows have higher intake capacity per kg BW when compared with other dairy cattle breeds. For example, in the previous study it was confirmed that German Black-and-White cows had only 80% of the digestive capacity per kg BW of Jersey cows (Smith and Baldwin, 1974) and also, Jersey cows have 21% higher rate of passage as compared to HF (Ingvartsen and Weisbjerg, 1993). The enhanced intake capacity is an advantage to Jersey cows under pasture-based management system, due to their ability to produce higher milk solids per unit area of pastures (Goddard and Grainger, 2004; Prendiville et al., 2010).

Effect of grazing systems

Unlike Jersey cows, the time spent in grazing by the HF varied between the grazing systems. When cows were on grazing in June and August, HF spent short time in grazing under SG as compared to KR system, which is associated with the quality of pastures. Since grasses at KR were maintained below 8 cm in the current study, it might lead to increased time spent in grazing. The short grasses under KR might require longer time to ingest the same amount of herbage as compared to SG system. However, in the current study, the trend has changed in September and October where HF spent longer time in SG as compared to KR unlike Jersey cows, which is difficult to explain. This requires additional information on herbage quantity and quality in both grazing systems in order to draw up conclusions. In the recent study, Zom et al. (2016) observed that HF spent long time in walking and lowest lying behaviour in SG as compared to continuous and rotational grazing systems.

The decrease in time spent in grazing might have an effect on milk production of HF cows. Dillon et al. (2003) noted that dairy cow's productivity under pasture-based production systems is affected by low voluntary herbage intake capacity, grass supply and quality. The persistence of Jersey cows in both grazing systems is advantageous in maintaining milk production and quality throughout the grazing season. Having spending longer time in grazing, the milk of Jersey cows is considered to be highly rich in PUFA, CLA and vitamins (Palladino et al., 2010). However, previous studies reported that HF milk has a higher amount of CLA as compared to Jersey cows under both pasture-based production systems and TMR (White et al., 2001). Pasture-based milk has higher beneficial health impact to humans due to higher levels of PUFA particularly the CLA and omega-3 fatty acids, vitamin A, E and β-Carotene (Hospers-Brands and van der Burgt, 2009; Kučević et al., 2016; Poulsen et al., 2012).

Effects of changing diet level

Jersey cows were not affected by changing the protein level in diet which influenced their consistency in percentage time spent on grazing throughout the experimental period. On the other hand, HF were much affected by reducing the protein level in diet associated with their higher energy requirements for maintenance and production, which was also reported by (Prendiville et al., 2010). The selection of HF has been exclusively for higher milk yield while fed on diets with high non-fibre carbohydrates (Sheahan et al., 2011) which contribute to the increased time spent on grazing when supplied with low protein diet in the current study. Previous studies suggested that the effects of changing diet levels between HF and Jersey cows were mostly observed on roughages as compared with the TMR diets associated with the levels of lipogenic precursors (Oldenbroek, 1988). In practical, Jersey cows require more lipogeic precursors as compared to HF to attain the optimal milk production, which can be obtained from the roughages (Goddard and Grainger, 2004; Oldenbroek, 1988). The persistency of Jersey cows in grazing under different levels of protein is an advantage because they are more forage-based and they often maintain their productivity with roughages of low quality (Goddard and Grainger, 2004). Furthermore, the persistence of Jersey cows under the harsh condition is an advantage since they can maintain important functional traits such as reproduction, longevity and fewer cases of lameness and hoof problems (Dillon et al., 2003a; Heublein et al., 2016).

Differences in rumination behaviour

Rumination can be defined as the process of regurgitation of fibrous ingested feed from the rumen to mouth followed by re-salivation and re-mastication, and swallowing back to the rumen (Prendiville et al., 2010; Welch, 1982). In the current study, HF cows spent longer time in rumination as compared to Jersey cows throughout the experimental period, which is consistent with the findings of (Aikman et al., 2008; Prendiville et al., 2010). However, the differences in time spent in ruminating reported by Aikman et al, (2008) was based on TMR while Prendville et al, (2010) observations were based on grazing under high-quality pastures, whereas the current study included two diet levels and two grazing systems. We observed that HF spent longer time in resting which provides an opportunity for more ruminating activities as compared to Jersey cows. Similar results were reported by Prendville et al. (2009, 2010) whereby HF cows spent more time in ruminating activities, mainly due to a large number of mastication as compared to Jersey cows. Also, previous studies emphasised that rumination and mastication are associated with feed intake and feed quality i.e. fiber content (Welch, 1982).

Performance evaluation and energy requirements of Jersey and Holstein-Friesian cows

Despite the fact that both breeds were under similar dietary levels and supplemented with 6 kg +/- 50 g/kg DM of concentrates per day, Jersey cows had significantly lower body weight, milk yield and energy intake as compared to HF. However, despite their smaller body size, lower energy intake and milk production, we observed that Jersey cows spent longer time in eating/grazing which is associated with the higher intake capacity per kg body weight. Similar studies by Prendiville et al. (2009) reported that Jersey cows have higher net energy efficiency (energy requirements/energy intake) as well as the gross energy efficiency (milk-solids/DMI) as compared to the HF cows. In practical, Jersey cows have higher milk solids per kg LW as compared to HF cows (Goddard and Grainger, 2004).

In the current study, it was expected that higher intake capacity per kg live weight of Jersey cows could have led to higher FPCM as compared to HF. However, Goddard and Grainger (2014) noted that higher milk solids per kg live weight could be attained if there are no changes in losses from faeces, urine, methane and heat. On the other hand, the differences in performance between Jersey and HF breeds is highly influenced by genotype and environment (GxE) interactions that need to be explored (Horan et al., 2006; McCarthy et al., 2007b). The GxE interactions occur when two different genotypes reacts differently in different environments (Nauta, 2009). The lower energy requirements for Jersey cows and the capability of producing higher yields of milk solids per unit area is an important determinant of farm productivity (Goddard and Grainger, 2004). Furthermore, Heublein et al. (2006) concluded that Jersey cows are the suitable breed for reducing feed-food competition with humans and monogastric animals such as pigs and poultry due to their less dependency on cereals.

5 Conclusion and recommendations

The combination of NEDAP and sensOor technology enables to differentiate the behavioural activities of cows such as eating/grazing, standing and rumination indoors and under pastures, respectively. However, with an exception for rumination activities, the current version of sensOor was overestimating and unable to differentiate between eating concentrate/roughages indoors and grazing on pastures. Therefore, further improvements are required in order to use sensOor as an independent tool in monitoring cow behaviour indoor and on pastures. The daily behavioural activities of cows i.e. eating, ruminating, active/not active are closely associated with productivity, health and welfare of cows. Therefore, the use of sensor technology could be an early warning tool in monitoring behavioural activities of cows. Further improvement of the sensOor is important due to its additional utility in monitoring fertility (heat detection), health and welfare traits in a close interval. This might be useful to both farmers and researchers in reducing time spent on monitoring behavioural activities of individual cows. Close observation of individual cows is the basis for the healthy herd and contributes to improving animal welfare as well as minimising the costs and losses associated with health problems and productivity.

The hypothesis that Jersey cows perform better under grazing condition as compared to the HF cows, and the effects of changing protein level in diet on the grazing behaviour of cows was endorsed in the current study. Based on the findings we concluded that Jersey cows outweigh HF in terms of percentage time spent in standing which is associated with their small body weight and low energy requirements. Also, Jersey cows spent longer time in eating/grazing associated with their greater feed intake capacity, mainly due to the large digestive tract per unit live weight as compared to HF cows. Furthermore, Jersey cows were not affected by changing protein level in the diet which influenced their consistency in the time spent on grazing throughout the experimental period. Therefore, the better performance of Jersey cows under pasture condition provides an opportunity for reducing feed-food competition for cereals which are also important for human and monogastric animals.

Despite the lower FPCM of Jersey cows, we see that they might be the suitable breed under predominant pasture-based production condition. The differences in production efficiency between Jersey and HF breeds might be associated with GXE interactions that need to be explored. However, the performance of the HF breed under pasture-based production system could be achieved through the optimized breeding programs and ensuring proper selection for important functional traits. More attention is required on incorporating feed intake and feed conversion efficiency during selection processes. Lastly, we see that the DMI of Jersey and HF cows can be calculated by the net energy method based on the energy requirements for lactation and maintenance and the net energy content of the herbage. Therefore, future research should analyse the chemical composition and energy values of herbage, in order to estimate the DMI of cows in KR and SG systems. Alternatively, the future research may include the n-alkane technique in estimating the DMI of individual cows.

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Annex 1. Information of the 62 cows involved in the study

No.	Cow ID	Experimental group	GrSyst	DietLv	Breed	Group (indoor)	Average FPCM (kg/day)	Average BW (kg)	NEL,required (MJ/day)	Number of lactation	Calving date	Days in milk	Experimental period	
													Start date	Last date
1	5	KR-H-Jer	KR	H	Jer	C	22.28	442.5	97.3	2	1/19/2016	195	4/18/2016	10/22/2016
2	10	KR-H-Jer	KR	H	Jer	C	25.64	395.3	105.9	2	3/5/2016	149	4/18/2016	10/22/2016
3	19	KR-H-Jer	KR	H	Jer	C	21.56	386.4	92.3	2	1/30/2016	184	4/18/2016	10/22/2016
4	21	KR-H-Jer	KR	H	Jer	C	18.86	409.8	84.7	2	4/13/2016	110	9/7/2016	10/22/2016
5	34	KR-H-Jer	KR	H	Jer	C	22.12	397.7	94.6	1	12/20/2015	225	4/18/2016	9/7/2016
6	47	KR-H-HF	KR	H	HF	C	27.12	597.4	120.4	2	3/8/2016	146	4/18/2016	10/22/2016
7	48	KR-H-HF	KR	H	HF	C	26.37	626.8	119.3	2	1/12/2016	202	4/18/2016	10/22/2016
8	55	KR-H-HF	KR	H	HF	C	20.78	571.1	98.5	2	1/17/2016	197	4/18/2016	10/22/2016
9	58	KR-H-HF	KR	H	HF	C	20.47	421.8	90.5	1	2/20/2016	163	4/18/2016	10/22/2016
10	61	KR-H-HF	KR	H	HF	C	28.40	584.2	124.0	2	2/15/2016	168	4/18/2016	10/22/2016
11	62	KR-H-HF	KR	H	HF	C	19.64	650.6	98.3	2	1/18/2016	196	4/18/2016	10/22/2016
12	71	KR-H-HF	KR	H	HF	C	25.69	551.2	113.6	2	2/15/2016	168	4/18/2016	10/22/2016
13	104	KR-H-HF	KR	H	HF	C	19.74	691.8	100.4	5	9/7/2015	329	4/18/2016	10/22/2016
14	125	KR-H-HF	KR	H	HF	C	29.95	582.9	129.2	2	1/21/2016	193	4/18/2016	10/22/2016
15	131	KR-H-Jer	KR	H	Jer	C	16.88	325.5	74.1	1	2/22/2016	161	4/18/2016	10/10/2016
16	135	KR-H-Jer	KR	H	Jer	C	16.60	397.2	76.9	2	2/8/2016	175	4/18/2016	10/10/2016
17	2	KR-L-Jer	KR	L	Jer	D	22.52	410.4	96.5	3	3/19/2016	135	4/18/2016	10/22/2016
18	9	KR-L-Jer	KR	L	Jer	D	21.96	389.0	93.6	2	1/18/2016	196	4/18/2016	10/22/2016
19	14	KR-L-Jer	KR	L	Jer	D	21.36	384.8	91.5	2	3/9/2016	145	4/18/2016	10/22/2016
20	18	KR-L-Jer	KR	L	Jer	D	21.93	376.4	92.9	2	1/8/2016	206	4/18/2016	10/22/2016
21	54	KR-L-HF	KR	L	HF	D	25.32	594.6	114.4	2	3/14/2016	140	4/18/2016	10/22/2016
22	56	KR-L-HF	KR	L	HF	D	25.29	600.2	114.5	2	2/14/2016	169	4/18/2016	10/22/2016
23	76	KR-L-HF	KR	L	HF	D	22.88	619.2	107.5	2	1/9/2016	205	4/18/2016	10/22/2016
24	87	KR-L-HF	KR	L	HF	D	15.82	416.0	75.3	1	2/15/2016	168	4/18/2016	10/22/2016

25	96	KR-L-HF	KR	L	HF	D	23.65	553.9	107.1	2	2/1/2016	182	4/18/2016	10/22/2016
26	97	KR-L-HF	KR	L	HF	D	21.92	620.5	104.4	3	1/16/2016	198	4/18/2016	10/22/2016
27	110	KR-L-HF	KR	L	HF	D	25.89	660.7	119.2	6	3/6/2016	148	4/18/2016	10/22/2016
28	123	KR-L-HF	KR	L	HF	D	26.27	536.5	114.8	3	3/16/2016	138	4/18/2016	10/22/2016
29	133	KR-L-HF	KR	L	HF	D	21.00	484.9	95.2	1	10/5/2015	301	4/18/2016	10/22/2016
30	134	KR-L-Jer	KR	L	Jer	D	14.31	324.9	66.0	1	1/21/2016	193	4/18/2016	10/10/2016
31	137	KR-L-Jer	KR	L	Jer	D	13.77	339.1	65.0	2	2/12/2016	171	4/18/2016	10/10/2016
32	1	SG-H-Jer	SG	H	Jer	A	23.51	416.6	100.1	3	2/10/2016	173	4/18/2016	10/22/2016
33	13	SG-H-Jer	SG	H	Jer	A	22.80	381.9	96.0	2	3/14/2016	140	4/18/2016	10/22/2016
34	15	SG-H-Jer	SG	H	Jer	A	20.07	444.1	90.3	2	1/17/2016	197	4/18/2016	10/22/2016
35	25	SG-H-Jer	SG	H	Jer	A	19.98	353.7	85.5	2	1/15/2016	199	4/18/2016	10/10/2016
36	41	SG-H-Jer	SG	H	Jer	A	16.25	317.9	71.7	1	2/4/2016	179	4/18/2016	10/10/2016
37	53	SG-H-HF	SG	H	HF	A	26.76	568.9	117.9	2	1/12/2016	202	4/18/2016	10/22/2016
38	60	SG-H-HF	SG	H	HF	A	27.52	508.1	117.6	2	2/20/2016	163	4/18/2016	10/22/2016
39	65	SG-H-HF	SG	H	HF	A	27.65	594.6	122.0	2	3/3/2016	151	4/18/2016	10/22/2016
40	68	SG-H-HF	SG	H	HF	A	25.00	657.7	116.1	2	2/20/2016	163	4/18/2016	10/22/2016
41	75	SG-H-HF	SG	H	HF	A	27.75	607.0	122.9	2	3/21/2016	133	4/18/2016	10/22/2016
42	92	SG-H-HF	SG	H	HF	A	22.06	519.7	100.3	2	1/28/2016	186	4/18/2016	10/22/2016
43	94	SG-H-HF	SG	H	HF	A	30.52	574.9	130.7	5	2/25/2016	158	4/18/2016	10/22/2016
44	101	SG-H-HF	SG	H	HF	A	23.88	626.3	111.1	3	1/18/2016	196	4/18/2016	10/22/2016
45	132	SG-H-HF	SG	H	HF	A	20.68	605.7	99.7	1	11/23/2015	252	4/18/2016	10/22/2016
46	136	SG-H-Jer	SG	H	Jer	A	21.16	383.3	90.8	1	2/12/2016	171	4/18/2016	10/22/2016
47	4	SG-L-Jer	SG	L	Jer	B	19.23	400.2	85.4	2	2/29/2016	154	4/18/2016	10/22/2016
48	7	SG-L-Jer	SG	L	Jer	B	22.88	411.6	97.8	2	2/23/2016	160	4/18/2016	10/10/2016
49	11	SG-L-Jer	SG	L	Jer	B	18.14	396.6	81.7	2	1/4/2016	210	4/18/2016	10/10/2016
50	22	SG-L-Jer	SG	L	Jer	B	16.92	446.5	80.3	2	4/23/2016	100	9/26/2016	10/22/2016
51	44	SG-L-Jer	SG	L	Jer	B	18.39	323.2	78.8	2	3/26/2016	128	4/18/2016	10/22/2016

52	50	SG-L-HF	SG	L	HF	B	21.14	566.0	99.4	2	2/9/2016	174	4/18/2016	10/22/2016
53	51	SG-L-HF	SG	L	HF	B	26.07	598.1	117.0	2	1/21/2016	193	4/18/2016	10/22/2016
54	52	SG-L-HF	SG	L	HF	B	26.25	533.7	114.6	2	1/19/2016	195	4/18/2016	10/22/2016
55	70	SG-L-HF	SG	L	HF	B	22.66	614.4	106.5	2	2/17/2016	166	4/18/2016	10/22/2016
56	81	SG-L-HF	SG	L	HF	B	21.66	487.3	97.5	1	2/15/2016	168	4/18/2016	10/22/2016
57	82	SG-L-HF	SG	L	HF	B	24.97	547.4	111.1	2	3/20/2016	134	4/18/2016	10/22/2016
58	106	SG-L-HF	SG	L	HF	B	25.11	559.9	112.1	3	2/28/2016	155	4/18/2016	10/22/2016
59	107	SG-L-HF	SG	L	HF	B	25.14	551.4	111.8	3	1/26/2016	188	4/18/2016	10/22/2016
60	130	SG-L-HF	SG	L	HF	B	19.29	530.6	91.8	1	10/12/2015	294	4/18/2016	10/22/2016
61	139	SG-L-Jer	SG	L	Jer	B	14.78	388.4	70.6	2	2/4/2016	179	4/18/2016	10/22/2016
62	140	SG-L-Jer	SG	L	Jer	B	14.85	386.0	70.7	1	2/9/2016	174	4/18/2016	9/26/2016