Behavioral genetics in Cattle- a review

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Abstract

Behavioral traits are the main controllable factors for domesticating cattle. The traits profoundly influence on the longevity of cattle and play a remarkable role in animal welfare assessment and animal ethics limitations determination. In the present study, the genetics of cattle behavior is discussed. Current breeding status of cattle behavioral traits is also reviewed, regarding the high individual variation of behavioral traits and almost high correlations between the traits and performance. Moreover, recent findings of characterizing quantitative trait loci (QTL) for behavioral traits of cattle is considered, as well as the most important problems in the breeding of cattle behavioral traits such as a large variety of methods which are used to evaluate the traits.

Keywords: Cattle behavioral traits: Behavioral genetics: Cattle performance: Cattle breeding: Animal welfare: Animal ethics

Introduction

There are main factors of the behavioral traits, including obedience and controllability, which can provide possibility of cattle domestication. Behavioral traits deeply affect cattle longevity are effective for assessment of animal welfare and determination of animal ethics ambit. Aurochs (*Bos primigenius*) were the first domesticated cows which were utilized for carrying and producing food such as milk, meat and blood. Cattle (*Bos taurus*) have been domesticated since approximately 8000 years ago (Pitt *et al.*, 2019). Cattle utilize senses to communicate. So, behaviors and communication of cattle depend on perceptions through seeing, hearing and smelling. The communication plays effective roles on solidarity and structure of cattle herd (Phillips, 2015).Cattle behaviors are communicable ways between animal and environment. They are able to respond their vital needs for species survival against different conditions of environment (Broom and Fraser, 2015). Animal behavioral reactions depend on animal senses and sensory behavior and environment. Cattles have senses (seeing, hearing, smelling, tasting and touch) as same as other mammals. The most important behavioral traits, particularly in domestication and breeding, are ability for gradual reducing fears of human, ability to subordinate gradually to human as a dominant living creature, ability to learning desirable behaviors and responses and ability for breeding and feeding by human. Breeders have considered behavioral traits as practical traits in breeding, since the influences of the traits on cattle longevity have been characterized (Pienaar *et al.*, 2015). Flexibility of behavioral traits of cattle which adapts with human-made conditions are used in domestication process and genetic breeding (Adamczyk, 2018). The traits are the foundation of human-animal relationship and consequently performance; as well as behavioral disorders including lameness, biting, tongue rolling, excessive licking and Self-treatment by buller steer syndrome (Friedrich *et al.*, 2015). Target *Bos taurus* strains selection is caused by behavioral characteristics and changes (Michenet *et al.*, 2016). Flexibility in behaviors enables animal to live in conditions created by human, as well as breeders to obviate requirements of cattle to achieve higher performance (Grandin, 2018).The behavioral traits are playing roles in breeding program, in many countries, although assessment of the traits is more difficult than productive traits. It could be caused by improvement of behaviors and genetics of cattle and effective environmental factors(Broom and Fraser, 2015). Therefore, the purpose of the study is review of the prominent issues in effective breeding of cattle behavioral traits, such as phenotypic evaluation and using molecular population genetics for estimation of genetic parameters and breeding values.

Behavioral traits definition

Cattle behavior is a brain-body function based on molecular pathways and genetic diversity. Behavioral flexibility and learning aptitude of cattle have been improved more than other mammals including rodents, cats and horses (Xu *et al*, 2018). The temperament, as a general animal trait, includes behaviors such as physical activity level, usual habits, feelings, consciousness and curiosity. According to several reports, animal temperament is caused by interaction of simulative-inhibitive reactions (Misheneva*et al*, 2018).Phillips (2015) has defined temperament as a main animal character in relation with human. Milking temperament of cattle has been defined as cattle milking behaviors, ease of manipulation and aggression during feeding (Krug*et al*, 2017). According these definitions, different methods are employed to evaluate cattle temperament in breeding programs and studies. Several methods have been categorized to evaluate cattle temperament in unlimited and limited scoring test system, free motion test and evaluation of maternal temperament (Bruno *et al.*, 2018).

Fear as a basic criterion for cattle temperament assessment

Temperament is the most important trait of animal for determination cattle perceptionand response to different conditions. This response could be a habitual behavior which has been possibly stable in different fields during cattle life. Observable appearances of cattle temperament are included reaction behaviors (Vogt *et al.*, 2017). Reaction against human is widely influenced by previous experiences related to communication with human and environmental changes. Fear is strong and emotional status to plays prominent roles to avoid potential dangerous conditions. Response for facing danger could be evaluated by behavioral and mental measurements (Lindahl *et al.*, 2016).Fear can be generally activated by environmental stimulators which are related to previous unpleasant experiences such as intense light, noise, sudden motions, touching and aggression. The most remarkable and observable reactions include active reaction (active defense and attacking), active avoidance (escaping and hiding) and inactive reaction (immobility, urine and feces) (figure 1). Active and inactive reactions can appear during challenging situations (Abramson and Kieson, 2016).There are considerable other types of behavioral patterns, such as standing position, facial expression, voices and releasing pheromones in fear appearance. Fear can be considered as the main mental factor. Although this is a temporary feeling, it can reflect the animal character. So, fear level has been considered as a main criterion for evaluating cattle temperament (Brand *et al.*, 2015).

It seems that fear, as the main factor, can affect quality of human–animal relationship (HAR). There can be found many applicable tests, designed based on reactions of cattle, pig, sheep, poultry and horse, to evaluate fear responses for measurement of HAR quality (Patterson-Kane and Johnson, 2018). Fear responses are very complex and cannot be automatically measured; it is required to evaluate criteria and indices related to fear. On the other hand, environment can mostly influence on cattle reactions; so, precision measurement of fear responses might be difficult, sometimes impossible. Behavioral responses could be observed as criteria and indices of fear, but not

measured directly. Diversity of environmental conditions in different studies is considered as another concern. Consequently, interpretation of results would be difficult (Menéndez-Buxadera*et al*., 2017).

Cattle temperament assessment for breeding purposes

Assessment of cattle temperament, such as milking, is considered for breeding purposes. There are different numeric criteria for the purpose. In many countries, including Denmark, Sweden and Finland, the assessment is categorized and estimated by consulters via artificial fertility techniques, when a cattle is firstly fertilized after calving (Ebinghaus *et al*., 2016). High scores belong to calm cattle or nervous one. According to animal behaviors observation in new environment, temperament assessment is mostly mental in beef cattle, although objective methods are used such as avoiding distance(Monk *et al*.,2018).

Objective measurements for cattle behavior assessment

Assessment of individual behavioral characteristics by application of objective measurements is essential to use cattle behavioral information for breeding. Reported studies can indicate some probabilities; as an example, it has been reported that the thickness and width of cylindrical bone of cattle is significantly related to cattle temperament (Parham *et al*., 2019).Convoluting facial hair near eyes of male cattle is considerable for objective measurement of temperament (figure2) (Bruno *et al*., 2018).

The aforementioned traits could be employed as accurate criteria for cattle temperament assessment; even probably other behavioral traits (Bruno *et al*., 2018). In last decade, technological developments have provided tools to develop systems for real time assessment of cattle behavior. Nowadays, cattle behaviors can be studied by Global Positioning System (GPS), Geographic Information System (GIS) in outdoor (pastures) or by tracking and monitoring systems such as X-Y-Z- Positioning in 3D and 2D space in indoor (figure3). Above reported methods could be employed for assessment of cattle temperament and other behavioral traits in different ages and growing conditions (Mora-Delgado et al., 2016).

Population genetics and behavioral traits of cattle

i) Diversity in behavioral traits

Behavioral traits of cattle are characterized by high significant individual diversity. Moreover, cattle are naturally observed in herd; they do several activities and utilize similar behavioral patterns. The high diversity allows animals to show their behaviors (Lim *et al*., 2016). There is high diversity of cattle behaviors related to feeding, rumination (figure 4), obedience to enter the milking room (Walker *et al*., 2015).In another report, high individual diversity has been observed in physical activity per a day for Holstein – Friesian cattle in welfare conditions (Adamczyk *et al*., 2017). Also, high diversity of Nellore cattle temperament has been assessed by using four scoring criteria (Verdon *et al*., 2018).

ii) Heritability of cattle behavioral traits andgenetic correlation with production traits

Generally, cattle heritable behavioral traits have been accepted as quantitative traits which are influenced by gene additive effects. The traits increasingly depend on single gene effects; for instance, temperament has been more considered among all the behavioral traits of the cattle. It has been indicated that heritability coefficient of temperament, estimated by using assessment methods in similar productive systems, has been significantly different with heritability based on animal age and genotype (Stephansen *et al*., 2018). There is also high diversity of heritability of cattle temperament (Miglior *et al*., 2017). Cattle temperament heritability parameters have been estimated 0.18-0.22 and 0.25 for Holstein – Friesian and Jersey, respectively (Mirza *et al*., 2015).In addition, heritability index of cattle temperament has been reported 0-0.61 and 0.11-0.31 for beef cattle (Vogt *et al*., 2017).Almost high heritability index (0.36, 0.44 and 0.5) have been recorded for nutritional behaviors (duration, and speed of feeding respectively; figure 5) of hybrid cattle of *Bos taurus* and *Bos indicus*. There is low or medium heritability for social and reproductive behaviors. Studies have been demonstrated that cattle temperament is a behavioral trait that correlates with function of milk, milk production and milking (Llonch *et al*., 2018). According to another research, cattle longevity is reduced by anxiety. Temperament and nutritional behavior are mostly related to meat performance trait (Olechnowicz *et al*., 2016). Also, there is almost high genetic relation between obedience and fertility in Limousine heifers (Valente *et al*., 2017).

iii) Cattle behavioral traits breeding

Temperament is the most considerable behavioral trait of cattle for breeders. Calm cattle breeding have been significantly increased by long term removing nervous cattle from breeding process; but there is a concern about this removing in both beef and dairy cattle. To exemplify, the results of dairy cattle population assessment have indicated that temperament of more than 90 percent of cattle which are milked is moderately calm or very calm (Hedlund and Løvlie, 2015); as well as results were considerable when more anxious cattle were selected for milking. In a study, a significant increasing of the average breeding value was found for the trait from 1980 to 1999. Comparison of breeding value has been made difficult in different countries due to various methods for assessment of dairy cattle temperament (Pelayo *et al*., 2016).

Fig 1 Active avoidance (being hidden)

Fig 2 Convoluting facial hair could be considered for Cattle temperament assessment

Fig 3 Tracker collar

Fig 4 "Ruminating" as a behavioral trait

Fig 5 Nutritional behaviors (duration, and speed of feeding)

Molecular genetics and cattle behavioral traits

i) Quantitative trait loci effect on cattle behavioral traits

About 6305 quantitative trait loci (QTL) have been characterized, mapped and designed for 416 different cattle traits. Discovering for effects of QTL on behavioral traits has been less successful than QTL characterization. The effects have been studied in other animals particularly mouse and farm animals such as poultry and pig (Brand *et al*., 2016). Researchers specifically concentrate on temperament and ability for habit and acclimatization more

than other behavioral traits. There are about 44 QTL on most of the chromosomes, except 2, 13, 17, 22, 23, 24 and 27, for temperament and ability for habit and acclimatization. The QTL can be mostly found on 1, 4, 9, 16, 19 and 29 (dos Santos *et al.*, 2017). The significant distribution in cattle genome which determines animal behavior, may be mainly caused by using different research methods within a trait. Also, primary results of gene evaluation show that there is a requirement to use increasingly molecular genetic markers for improvement of applicability of studies to discover candidate genes for cattle behavioral traits (Laine and van Oers, 2017).

ii) Candidate genes for cattle behavioral traits

Genetic maps structure of several farm animals species and efforts to improve animal welfare in different key systems, have increased research on genetics of behavioral traits. Identifying molecular mechanisms of behaviors might be effective to understand common problems in many productive fields of animal such as manipulation, sensitivity and tolerance to stress or acclimation to different productive systems (Chen *et al.*, 2015). It is supposed that characterizing QTL of cattle behavioral traits causes to characterize candidate genes which are near the genetic markers and highly effect on the specific trait; nevertheless, the method is not generally effective due to high complexity of animal individual behaviors expression and reactions to environment (Neave *et al.*, 2018). Up to now, just a few published studies have reported the genes which might contribute to appearance of temperament, nutritional and reproductive behaviors of cattle. The reports have studied polymorphism of the genes which are active in biosynthesis of stress hormones, neural peptides and neurotransmitters (Van Engen and Coetzee, 2018). In a study, expression of gene which encodes heat shock protein is used to primarily diagnose symptoms of bovine respiratory disease complex. According to the results, it is demonstrated thatthe gene is expressed to response to stress (Lipkin *et al.*, 2016). Polymorphism of the gene of the bovine neuropeptide Y5 receptor shows that the gene can potentially regulate Y5 activity and might play key role in regulation of beef cattle appetite and nutritional behavior (Adamczyk, 2018).Also, it is indicated that there can be found correlation between expression of GFRA2 (GDNF Family Receptor Alpha 2) gene and residual feed intake (Higgins *et al.*, 2018). In another similar study, polymorphism of the gene, encoding melanocortin 4 receptor (MC4R), has been employed as a genetic marker of cattle commercial traits. It is indicated that the gene probably affects feed intake rate and nutritional behaviors (Prihandini*et al.*, 2017). Identification of genes which can affect cattle behavioral traits, showed that there is a correlation between gene expression in cattle ventral tangential region and appearance of stress in high-producing Holstein– Friesian cattle (Wiener, 2015).Genes of several neurotransmitters and neurotransmitter receptors (OXT, AVP, POMC and MCHR1) are expressed to collaborate in appearance of estrous behaviors such as social and sexual nervousness, stress and nutrition motivation (Imran *et al.*, 2018).

Conclusion

Characterizing cattle behaviors is essential to enhance cattle performance based on animal welfare and rights. The effect of light, hormones and genetic factors on cattle behaviors would be studied more. Cattle behavioral traits could be increasingly considered in recent breeding program due to importance of the traits. It seems that there is hopeful prospect to develop behavioral traits with respect to molecular and population genetics; because these traits are significantly various and favorably correlative with other traits such as productivity. Nevertheless, it is required to provide obvious phenotypes of cattle individual traits and use objective methods as criteria of breeding values in productive systems for practical applications of behavioral genetics research.

Acknowledgement

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