UDC 637.3:547.962.3:579.254.22
ISSN 1330-9862

review

(FTB-1013)

Lactoprotein Genetic Variants in Cattle and Cheese Making Ability

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Received; January 19, 2000
Accepted: May 2, 2000

Summary

Cheese making ability of milk is associated with high contents of protein, casein (CN) and fat, high casein number, short rennet coagulation time (RCT), high curd firmness (CF) and with a high cheese yield. For the four CN loci, as well as for the β-lactoglobulin (LG)- and α-lactalbumin (LA) locus, more than 60 genetic variants have been observed. However, most of these variants have not yet been investigated with regard to their cheese making ability. In Holstein Friesian cows κ-CN BB is associated with a higher protein and casein content of milk than κ-CN AA. However, in Simmentals and in Brown Cattle this association is not so clear; a higher fat content of milk seems to be related to β-LG BB when compared with β-LG AA. In many publications β-LG BB also showed a higher casein content than β-LG AA. All publications referring to the casein number report that milk containing β-LG BB has an approximately 3 % (absolute) higher casein number than milk containing β-LG AA. Regarding the genotypes α_{s1}-CN BC and CC contradictory results for the RCT and CF values have been published when compared with α_{s1}-CN BB milk. β-CN BB showed in all publications the shortest RCT among all β-CN genotypes, whereas the reported results for CF of this genotype compared with the types A^1A^2 or A^2A^2 are conflicting. From the majority of the published data it may be concluded that milk containing κ-CN BB has significantly shorter RCT and higher CF than κ-CN AA milk. All rare genotypes at the κ-CN locus, such as AC, BC, AE, BE and EE, had worse RCT values than κ-CN BB milk. CF of κ-CN genotypes increases in the order AE/AA<AB/AC<BC/BB. In most investigations involving Parmiggiano-Reggiano, Cheddar and other cheese varieties higher yields of cheese were found, ranging from 0.3 to 10 %, in favour of κ-CN BB compared with κ-CN AA. Due to the higher casein number associated with β-LG BB, higher yields of cheese were reported in literature (range 1 to 10 %) for this genotype than for β-LG AA. In summary, κ-CN B and β-LG B are the most advantageous variants with respect to cheese making ability. However, in most publications attention was focused on the effects of a single milk protein locus but due to the tight linkage between the casein loci effects of haplotypes should be studied more extensively.

Key words: bovine lactoproteins, genetic variants, milk composition, cheese making ability

Introduction

The first report on the occurrence of β-lactoglobulin (β-LG) A and B in various British cattle breeds was published in 1957 *(1)*. Since then, many new genetic variants have been described due to the availability of improved

* Invited lecture

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Table 1. Genetic variants of milk proteins* in cattle

Milk protein	Common variants	Rare variants In Bos taurus breeds	Variants found only in non-European breeds
α_{s1}-Casein	B, C	A, D, F, G	E, H, X, X', Y
α_{s2}-Casein	A	B, D	C
β-Casein	A^1, A^2, B	A^3, A^5, C, E, F, G [B^2]	A4, A', $A^3_{Mongolie}$, B_Z, D, H
κ-Casein	A, B	C, E, F, G, H [A^1], [B^2], [F], [I]	A_{1SS}, [G], [H], J, X, Y
β-Lactoglobulin	A, B	C, D, H, I, J, W	Dr, D_{Yak}, E, F, G, H, X, Y, Z
α-Lactalbumin	B	A	C

* Update of lactoprotein variants (*6,32,33*); α_{s1}-CN H (*34*), α_{s1}-CN X (*35*), α_{s1}-CN X' (*36*), α_{s1}-CN Y (*35*), β-CN F (*37*), previously β-CN X, (*37*), β-CN G (*38*), β-CN H (*39*), β-CN B^2 (*40*), breed not stated, κ-CN F (*41*), κ-CN G (*42*), κ-CN H (*43*), κ-CN A_{1SS} (*44*), κ-CN [G] (*45*), κ-CN [H] (*45*), κ-CN J (*34*), κ-CN X (*46*), κ-CN Y (*46*), κ-CN [A_1] (*47*) in Bos indicus x Bos taurus, Bos indicus), κ-CN [B_2] (*48*), κ-Cn [F] (*49*), breed not stated, κ-CN I (*47*) in Bos indicus x Bos taurus, β-LG I (*50*), β-LG J (*51*), previously β-LG X, (*52*), β-LG X (*35*), β-LG Y (*46*), β-LG Z (*46*)

methods for the detection of genetic polymorphism, such as isoelectric focusing, column chromatography, HPLC as well as polymerase chain reaction (PCR) and restriction fragment length polymorphism (RFLP) at the DNA level. Particularly in the last decade the number of newly detected variants has increased dramatically. Table 1 summarises the known genetic variants of milk proteins.

The common variants of lactoproteins are present in all cattle breeds. However, many minor variants occur only in non-western breeds such as yaks, Indonesian breeds (Bali cattle/banteng), zebus or in *Bos indicus* x *Bos taurus* crosses. The frequency of genetic variants differs from breed to breed and the frequency distribution of the various milk protein variants in different breeds has been discussed comprehensively *(2)*. In the last 20 years numerous investigations have focused on the association between certain genetic variants of milk proteins and yield traits, milk composition and technological properties of milk. The scope of these studies was to explore the possibility to select for specific protein variants related to economically important traits. The aim of this review is to present a summary of the association between lactoprotein genetic variants and cheese making ability. This summary will not only refer to the more common variants α_{s1}-CN B and C, β-CN A^1,A^2 and B, κ-CN A and B and β-LG A and B, but also to rare variants such as α_{s1}-CN G, β-CN C, κ-CN C, E and G, and β-LG C and D. More detailed reviews on the relationship between milk protein polymorphism and milk composition and technological properties of milk can be found in the literature *(3–9)*.

Genetic Variants and Cheese Making Ability

Cheese making ability depends on quantitative and qualitative characteristics of milk. The most important variables in milk composition are casein and fat contents. Furthermore, casein number and in particular coagulating properties of milk proteins are influencing cheese making ability considerably. The coagulating properties themselves depend on casein content but also on important differences in coagulating behaviour among different lactoprotein genotypes. This is confirmed by greater differences in cheese making ability among different lactoprotein genotypes as it would be expected only from quantitative differences among them.

Content of protein and casein

Table 2 shows the influence of genetic variants of milk proteins on the contents of protein and casein in milk. Regarding the α_{s1}-CN locus, variant B occurs in most breeds with a frequency of at least 90 %; therefore the genotype BC is rare and genotype CC is extremely rare. In most publications α_{s1}-CN C was found to be associated with a slightly higher content of protein and casein than variant α_{s1}-CN B. There is only a limited number of investigations concerning the β-CN locus.

Due to the large number of alleles occurring at this locus (resulting in many genotypes within the same breed) the reports on the association between β-CN variants and the content of protein and casein are conflicting. It has to be stated that some studies did not distinguish between the different β-CN A variants (A^1, A^2 and A^3). This has been shown in the comprehensive investigation in Fleckvieh (Simmental) and Brown Swiss cattle (2208 and 2057 lactations, respectively) (*10*). Nearly all investigations of the association between κ-CN genetic variants and milk composition showed that κ-CN BB milk has a higher content of protein and casein than κ-CN AA milk in Holstein Friesian and related breeds. The average difference in protein and casein content between these two genotpyes was estimated to be 0.08–0.10 % (Table 2). However, no effect of the genotypes κ-CN BB or AA on the content of protein and casein in milk has been observed in Fleckvieh and Brown Swiss cattle (*10*). The reports of the association between variants A and B of the β-LG locus and protein content of milk are contradictory. About 50 % of the studies report a higher level of milk protein content for variant β-LG A than for variant B, whereas the other half of the investigations observed the contrary. As to the casein content nearly all publications showed that milk containing β-LG BB has a higher concentration of casein than milk containing

Table 2. Effect of genetic variants of milk proteins on the contents of protein and casein

Locus/Component	Order (tendency) of genotypes	Remarks/Literature
α_{s1}-Casein		
Protein content	BC/CC > BB	– (*3,5–8*) – Mostly no significance between genotypes
Casein content	BC/CC > BB	– (*3,5–8*) – Mostly no significance between genotypes
β-Casein		
Protein content	–	– (*3,5–8*) – No distinct tendency between genotypes
Casein content	–	– (*3,5–8*) – No distinct tendency between genotypes
κ-Casein		
Protein content	BB > AB > AA	in Holsteins: – (*3–8*) – Mostly significance between genotypes – BB approx. 0.08–0.10 % > AA
	–	in Simmental and Brown cattle: – No distinct tendency between genotypes (*10*)
Casein content	BB > AB > AA	in Holsteins: – (*3–8*) – Mostly significance between genotypes – BB approx. 0.05–0.08 % > AA
	–	in Simmental and Brown cattle: – No distinct tendency between genotypes (*10*)
β-Lactoglobulin		
Protein content	–	– No distinct tendency between genotypes (*3–9*)
Casein content	BB > AB > AA	– (*3–9*) – BB approx. 0.10 % > AA
	BC>BB>AB	(*11*)
	BC>BB>AB>AD>BD>AA	(*12*)
	BD>BB>AD>AB>AA	(*10*)

β-LG AA (BB approx. 0.10 % > AA) (Table 2). The casein level of β-LG AB milk was usually found to be intermediate between the casein values of β-LG AA and BB. Milk with the genotype β-LG BC had an even higher casein content than β-LG BB milk (*11,12*), whereas higher content of casein for β-LG D compared to β-LG A (Table 2) was observed (*10,12*).

Content of fat

Milk fat globules are trapped during the formation of curd and therefore milk with higher fat content results in better cheese yield. There are many reports that relate genetic variants of the α_{s1}-, β- and κ-CN locus to fat content. However, the results for the different genotypes of the 3 loci are very contradictory and therefore no clear conclusion can be drawn about the association of genotypes at these 3 loci with fat content. Regarding the variants of β-LG, most of the publications have shown that β-LG B favours a higher fat content than β-LG A.

Casein number

Casein number is defined as a ratio between the casein amount and total amount of proteins in milk, multiplied by 100. It is an important parameter for the cheese-yielding capacity of milk. Few publications deal with the relationships of the genotypes of the α_{s1}- as well as the β-CN and the casein number and no distinct associations have been reported (Table 3). Similarly little information is available for κ-CN, but the majority of studies observed the decreasing order for casein number: BB > AB > AA. Numerous studies have been published on the association between β-LG genotypes and casein number. All publications have confirmed that the casein number decreases in the order BB > AB > AA and that milk containing β-LG BB has approximately 3 % (absolute) higher casein number than milk containing β-LG AA. The casein number can be calculated for different genotypes of β-LG from the values for protein and casein content in Fleckvieh breed (*10*) revealing the following order: BB > BD > AB/AD > AA. The casein number has been calculated from the protein and casein data (*13,14*) showing the similar casein number for β-LG genotypes BC and BB (*12*). The highest casein number among all investigated β-LG genotypes (Table 3) has been shown for β-LG genotype BC (*12*). The review of the impact of different CN loci and β-LG locus on the casein number has been already published (*15*).

Coagulating properties

Rennet clotting time, curd firming rate and curd firmness characterise the coagulating properties of milk.

Formagraph or kjelograph are most frequently used for the measurement of these parameters. Due to the high correlation between rennet clotting time and curd firming rate, only rennet clotting time and curd firmness are discussed. The first report on a relationship between coagulating properties of milk and genetic variants of milk proteins was published in 1967 (*16*). This association has been comprehensively investigated as shown in Tables 4 (rennet clotting time) and 5 (curd firmness). As it can be seen from Table 4, milk with the genotype α_{s1}-CN CC or BC has a shorter rennet clotting time than milk with α_{s1}-CN BB genotype. Significantly shorter rennet clotting time for α_{s1}-CN BG as compared to α_{s1}-CN BB has been reported (*17*). All publications report that milk containing β-CN BB, has the shortest rennet clotting time among β-CN genotypes. The other genotypes of this locus seem to differ only slightly in their rennet clotting times with the exception of β-CN CC which has significantly shorter rennet clotting time than β-CN A^1A^1 or A^1A^2 or A^2A^2 (*18*). The majority of published reports have dealt with the association between rennet clotting time and κ-CN A and B, respectively. With exception of one (for details see Lodes *et al.*, 1995), in all other investigations has been observed that rennet clotting time increased in the order of κ-CN BB < AB < AA. In various reports, differences in the rennet clotting time between κ-CN BB and AA varied between 10 and 40 %, the average difference being approximately 20 % between these two genotypes. The variants κ-CN E, C and G seem to have a similar detrimental effect on rennet clotting time as κ-CN A (*14,19–21*) (Table 4). The reports on the relationship between β-LG variants and rennet clotting time are contradictory.

Concerning the association between genetic variants and curd firmness (Table 5), α_{s1}-CN BC produces a gel with higher firmness than milk containing α_{s1}-CN BB. However, with the exception of β-CN CC, there seems to be no distinct differences between the values of curd firmness of the different genotypes of β-CN. Concerning the very conflicting results, the same seems to be true also for the β-CN BB genotype compared with the other β-CN genotypes. At standardised pH, a significantly weaker curd for β-CN CC compared with β-CN A^1A^1, A^1A^2 or A^2A^2 has been observed (*18*). All publications concerning κ-CN variants A and B report the decreasing order of curd firmness: BB > AB > AA. Milks with the κ-CN genotypes AE or EE (*14,19,20*) or κ-CN BG or AG (*21*) also show a weak gel firmness, whereas the reports on κ-CN BE, compared with κ-CN AB, are not consistent. Very interesting are the genotypes κ-CN AC and BC; as shown in Table 4, these genotypes had the worst rennet clotting times of all κ-CN genotypes (*20*). How-

Table 3. Effect of genetic variants of milk proteins on casein number

Locus/Component	Order (tendency) of genotypes	Remarks/Literature
α_{s1}-Casein	–	no influence of genotypes
β-Casein	–	no influence of genotypes
κ-Casein	BB > AB > AA	– (*3,4,6,7*)
β-Lactoglobulin	BB > AB > AA	– (*3,4,6,7,15*) – BB approx. 3 % (absolute) > AA – AB intermediate between BB and AA
	BC/BB>AB>AA BB/BC>AB>AA	(*13*) cited in (*12*) (*14*) cited in (*12*)
	BC>BD/BB>AB>AD>AA BB>BD>AB/AD>AA	(*12*) (*10*) calculated from Fleckvieh data

Table 4. Effect of genetic variants of milk proteins on rennet clotting time

Locus/Component	Order of genotypes according to the length of the rennet clotting time	Remarks/Literature
α_{s1}-Casein	CC/BC<BB BG < BB	(*3,5–8*) (*17*)
β-Casein	BB < all other β-casein phenotypes	(*3,5–8*)
	$BB<A^1B<A^2C<A^2B<A^1A^1<A^1A^2/A^2A^2$ $CC<A^1A^1/A^1A^2/A^2A^2$	(*20*) (*18*)
κ-Casein	BB<AB<AA	(*3–8*) – BB approx. 20 % < AA
	BB<AB<AE<EE<AE<AA AB<BE<AA/AE AB<AA<AE BE<BB<AB<AE<AA <BC<AC AB<BB<AA<BG<AG	(*14*) (*19*) (Fleckvieh breed) (*19*) (Schwarzfleckvieh breed) (*20*) (*21*)
β-Lactoglobulin	–	contradictory reports (*3–9*)

Table 5. Effect of genetic variants of milk proteins on curd firmness

Locus/Component	Order of genotypes according to curd firmness	Remarks/Literature
α_{s1}-Casein	BC>BB	(*3,5–8*)
β-Casein	–	– no distinct tendencies between genotypes (*3,5–8*)
	CC<$A^1A^1/A^1A^2/A^2A^2$*	(*18*)
κ-Casein	BB>AB>AA	(*3–8*) – BB approx. 50 % > AA
	BB>AB>BE>AA/EE/AE	(*14*) (Holstein Friesian)
	BB>BE>AB>EE>AA/AE	(*14*) (Angler breed)
	BE>AB>AA>AE	(*19*) (Fleckvieh breed)
	AB>AA>AE	(*19*) (Schwarzfleckvieh breed)
	BB/BC>AC/AB>AA>BE>AE	(*20*)
	BB>AB>AA>BG>AG	(*21*)
β-Lactoglobulin	–	contradictory reports (*3–9*)

* at standardized pH value

Table 6. Effect of genetic variants of κ-casein on cheese yield

Cheese variety	Approx. yield increase κ-casein BB > AA (%)	Literature
Parmigiano-Reggiano	8.5	(*22*)
Parmigiano-Reggiano	9.8	(*53*)
Parmigiano-Reggiano	5.5	(*53*)
Svecia	0.3 n.s.[1), 2)]	(*54*)
Cheddar	5	(*55*) cited in (*56*)
Cheddar	4 (P<0.05)	(*27*)
Camembert	3 (P<0.05)	(*28*)
Cheddar	AB sig. > AA[3)]	(*57*)
Cheddar	3	(*58*) cited in (*56*)
Cheddar	6.2 (P<0.01)	(*8*)
Cheddar	6.1 (P<0.01)	(*59*)
Cheddar	BB > AA[3)]	(*60*)
Cheddar	5.5	(*61*)
part-skim Mozzarella	5.5 (P<0.05)	(*62*)

[1)] AB + BB *vs.* AA
[2)] n.s. = not significant
[3)] no exact value listed

Table 7. Effect of genetic variants of β-casein on cheese yield

Cheese variety	Approx. yield increase (compared genotypes)	(%)	Lit.
Cheddar	$A^1A^1 > A^1A^2$	4.5 (P<0.05)*	(*27*)
Beaufort	$A^1A^1/A^1A^2/A^2A^2$>CC	15 (P<0.001)	(*18*)

* calculated from »adjusted yield« data

Table 8. Effect of genetic variants of β-lactoglobulin on cheese yield

Cheese variety	Approx. yield increase β-lactoglobulin BB>AA (%)	Literature
Parmigiano-Reggiano	2.6	(*63*)
Svecia	3.5 (P<0.05)	(*54*)
Cheddar	2.4 (P<0.01)	(*64*)
Cheddar	7.9 (P<0.05)	(*65*)
Cheddar	up to 10	(*66*)

ever, as shown in Table 5, milks with κ-CN BC or AC show a curd firmness which is nearly as good as that of milk with κ-CN BB (*20*). The reports on curd firmness of the different β-LG genotypes are also conflicting.

Cheese yield

Because of its economic significance, the cheese yield is the most important trait influenced by cheese making ability. In general, it is difficult to compare different experiments dealing with cheese yield because of different protein and fat content in the raw milk, different experimental scales and conditions applied and differences in statistical evaluation of the experiments. The first report on the relationship between cheese yield and κ-CN AA and κ-CN BB, respectively, was published in 1976 (*22*). They observed that milk containing κ-CN BB showed 8.5 % higher cheese yield than κ-CN AA milk when producing Parmigiano-Reggiano cheese. Table 6 summarises the reports on the association between cheese yield and κ-CN A and B, respectively. According to Table 6, all investigations report higher cheese yields (ranging from 0.3 to 9.8 %) in favour of κ-Cn BB genotype. In two experiments with Gouda cheese production, a slightly higher conversion of total nitrogen of milk into cheese nitrogen was observed for κ-CN BB compared to κ-CN AA (*23*). During the production of Tilsit type cheeese, 2.7 % higher protein conversion in κ-CN BB milk compared to κ-CN AA milk was observed (*24*). Erhardt *et al.* (*25*) investigated cheese yield of milks with high (25.8 %) and low (9.7 %) κ-CN content for butter cheese production under industrial conditions and found 2.3 % higher cheese yield in the group with higher κ-CN content. In contrast to the results in Table 6, the experiments with Cheddar cheese showed a higher cheese yield for milk with κ-CN AA than for κ-CN BB milk (*26*). This result might have been due to

Table 9. % Frequency of genotypes in different breeds, advantageous for certain variables of cheese making ability

Advantageous Genotype	Variable	Frequency[1)]			
		Breed			
		Holstein Friesian[2)]	Simmental/ Fleckvieh[3)]	Brown Swiss[4)]	Jersey[5)]
κ-Casein BB	Protein content Casein content Rennet coagulation time Curd firmness Cheese yield	2–3	5–10	24–35	31–40
β-Casein BB	Rennet coagulation time	< 1	< 1	3–4	8–10
β-Lactoglobulin BB	Fat content Casein number Cheese yield	32–37	20–25	24–35	25–41

[1)] only publications between 1989 and 1999 were regarded

[2)] *67–69,14,70,71*

[3)] *72,70,19,71*

[4)] *72,70,19,73*

[5)] *69,70,71*

the very low protein content of the processed κ-CN BB milk.

There are only two reports concerning β-CN variants and cheese yield (Table 7). The β-CN genotype A^1A^1 was with 4.5 % higher cheese yield significantly better than genotype A^1A^2 (27). In addition, the yield of cheese from cows with β-CN A^1A^1, A^1A^2 or A^2A^2 was 15 % higher (*18*) than that of milks with genotype β-CN CC ($P < 0.001$).

Reports on the association between β-LG A and B with cheese yield are summarized in Table 8. Higher yields were associated with β-LG BB as opposed to β-LG AA milks (ranging from 2.4–10 %) in all listed publications. However, no influence of the β-LG genotype on cheese yield was observed in the study of Marziali and Ng-Kwai-Hang (*27*). The total nitrogen retention in the curd from milk containing β-LG BB was 76.41 % *vs.* 73.51 % in β-LG AA milk (*28*). In two trials with Gouda cheese (*23*), and as can be derived from the published data in this paper, conversion of milk nitrogen into cheese nitrogen was approximately 3 % and 2.7 % for β-LG BB and β-LG AA, respectively.

Concluding remarks

Table 9 summarises the literature results with emphasis on those genotypes, which have been consistently found to be advantageous for certain traits related to cheese making ability. It can be inferred that the most interesting genotypes are κ-CN BB and β-LG BB. The β-CN genotype BB is only consistently related to a short rennet clotting time. Table 9 also shows the frequency of the advantageous genotypes in different known dairy breeds. However, there are many more genotypes (than those listed in Table 9) of the different CN loci and of the β-Lg locus, which have been investigated in order to estimate their cheese making ability. In many cases results from different studies are not comparable or even conflicting for the following reasons: population size, breed(s) of investigated animals, frequency of genotypes under consideration, methods of measuring traits (test day or lactation data), and most importantly, the method of statistical analysis (adjustment for factors influencing the measured traits such as, the age of cows, season, stage of lactation, health status etc.) (*6*). In some cases the reason for contradictory results on the association between certain genotype and particular trait might be the fact that observed association is not due to the effect of a single allele, but to the effect of linked alleles (haplotype). In most cases in the literature and also in this paper only the effects of single alleles were discussed. Due to the close linkage between casein genes, it is important to investigate more extensively the effects of haplotypes on production traits and processing ability of milk. At present only little information is available about the associations between haplotypes, milk composition (*10,29–32*) and casein number (*29*). The relationship between haplotypes and coagulating properties of milk (*30*), and association between haplotypes and cheese yield (*29,30*) has been studied. Due to the conflicting results of haplotype comparisons further discussion and analysis of experimental designs will be omitted.

At present, discussion among breeders is going on whether they should select for κ-CN B and β-LG B. The most appropriate breeding strategy (direct selection for k-CN B, selection index or breeding for favourable haplotypes) is under discussion as well (*33*).

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Genetičke varijante laktoproteina stoke i sposobnost proizvodnje sira

Sažetak

Proizvodnja sira iz mlijeka povezana je s velikim udjelom proteina, kazeina (CN) i masti, visokim kazeinskim brojem, kratkim vremenom koagulacije renetom (RCT), velikom čvrstoćom gruša (CF) i velikim iskorištenjem na siru. Postoji više od 60 genetičkih varijanti za četiri CN lokusa, kao i za lokuse β-laktoglobulina (LG) i α-laktalbumina (LA). Zasada najveći broj tih varijanti još nije istražen s obzirom na njihovu sposobnost stvaranja sira. U mlijeku Holstein frizijskih krava κ-CN BB povezan je s većim udjelom proteina i kazeina nego κ-CN AA. Nasuprot tome, kod simentalki i smeđih krava to povezivanje nije tako jasno; u usporedbi s β-LG AA izgleda da je veći udjel masti u mlijeku povezan s β-LG BB. U mnogim podacima iz literature objavljeno je da β-LG BB ima veću količinu kazeina od β-LG AA. U svim radovima koji donose podatke o kazeinskom broju vidi se da mlijeko što sadržava β-LG BB ima približno 3 % (apsolutno) viši kazeinski broj od mlijeka s β-LG AA. Što se tiče genotipova α_1-CN BC i CC objavljeni su proturječni rezultati za vrijednosti RCT i CF u usporedbi s genotipom α_{s1}-CN BB. U svim publikacijama β-CN BB pokazuje najkraće vrijeme koagulacije renetom (RTC) između svih β-CN genotipova, dok objavljeni rezultati za CF toga genotipa nisu u skladu ako se usporede s tipovima A^1A^2 ili A^2A^2. Na osnovi niza objavljenih podataka može se zaključiti da mlijeko koje sadržava κ-CN BB ima bitno kraći RTC i viši CF od κ-CN AA mlijeka. Svi rijetki genotipovi na κ-CN lokusu, kao AC, BC, AE, BE i EE, imaju slabije RTC vrijednosti od κ-CN BB. Vrijednost CF kod κ-CN genotipova povećava se u nizu AE/AA<AB/AC<BC/BB. U najvećem broju istraživanja, koja su obuhvatila »Parmiggiano-Reggiano«, »Cheddar« i druge vrste sira, utvrđeno je da je iskorištenje na siru od 0,3 do 10 % bolje kod κ-CN BB u usporedbi sa κ-CN AA. S obzirom na viši kazeinski broj povezan s β-LG BB, u literaturi je objavljeno veće iskorištenje na siru (u rasponu od 1 do 10 %) za taj genotip nego kod β-LG AA. Stoga su κ-CN B i β-LG B najpovoljnije varijante s obzirom na sposobnost stvaranja sira. Međutim, u najvećem broju publikacija pozornost je bila usredotočena na utjecaj samo jednog mliječnog proteinskog lokusa, ali zbog usporedne povezanosti kazeinskih lokusa haplotipova, istraživanje bi trebalo biti puno intenzivnije.