RESEARCH PAPERS

NOMENCLATURE OF THE PROTEINS OF COW'S MILK—SECOND REVISION

Report of the Committee on Milk Protein Nomenclature, Classification, and Methodology of the Manufacturing Section of ADSA for 1963-64

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ABSTRACT

The Nomenclature Committee has given particular attention to genetic polymorphism in the proteins of cow's milk, and has adopted a nomenclature scheme which embraces genetic designations. The β-lactoglobulins are to be referred to as β-lactoglobulins A, B, and C. Three genetic forms of β-casein have been reported to occur either singly or in pairs in the milk of individual cows, and are appropriately referred to as β-caseins A, B, and C. The term α_{s1}-casein has been recommended and refers to those components of the α-casein complex that are precipitated by calcium and stabilized by κ-casein against precipitation by calcium. They constitute the major proportion of the α_s-caseins, and have been reported to exist in three genetic forms, A, B, and C. The genetic forms of α_{s1}- and β-caseins can be conveniently identified by their relative mobilities by zonal electrophoresis.

The nomenclature of the proteins of cow's milk, and particularly of the casein components it contains, has been in a transient state in which the application of specific terminology has become more and more difficult. Since the 1960 report of this Committee (12) numerous developments, especially in the casein field, have increased the confusion in nomenclature. The discovery of genetic variants in α_s- (34, 67, 68) and β-caseins (1, 2) may, however, serve to clarify and simplify the complex situation.

The need for clarity in the nomenclature of milk proteins has prompted the Committee to present this second revision in which it discusses (a) new discoveries concerning genetic polymorphism of milk proteins; and (b) comparative evaluations of casein components given different designations by their authors, but which are possibly identical. The Committee proposes a nomenclature system to allow for the inclusion of further components of casein and other proteins which may yet be isolated and characterized.

Certain conclusions have been reached by this Committee: (1) New techniques and improved versions of established methods, such as zonal electrophoresis techniques, are of considerable value in determining the purity and genetic heterogeneity of milk proteins. Contrary to moving boundary electrophoresis methods they are suitable, for example, for studying the heterogeneity of the α-casein complex. (2) The discovery of additional genetic variants of whey proteins and caseins is likely. Classification of such new variants should conform with the established scheme of designa-

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tion of genetic variants, e.g., β-lactoglobulins A and B. (3) The nomenclature of newly isolated components should continue to be left to the discretion of individual researchers, providing that the components differ in fact and not only in purity, from previously reported components.

Whey proteins and some minor proteins. Since the 1960 report little additional information affecting the nomenclature has been forthcoming on the whey proteins. The exception has been the discovery of β-lactoglobulin C by Bell (8). The genetics of β-lactoglobulins A and B (locus symbols Lg^A and Lg^B) had been reported by Aschaffenburg and Drewry (5). By zonal electrophoresis at alkaline pH's, β-lactoglobulin C (locus symbol Lg^C) migrates slower than β-B. Thus, the correct terminology for these proteins on a genetic basis is β-lactoglobulins A, B, and C. Bell has stated that all three genetic forms of β-lactoglobulin could occur together in the milk of an individual cow, but has retracted this statement (8a). Kalan et al. (33) have recently reported the amino acid composition of β-C as was previously reported on β-A and β-B (18, 51). Calculated from a molecular weight of 36,000, the following residue differences are observed among β-lactoglobulins A, B, and C, respectively: ASP—32, 30, 30; GLU—50, 50, 48; GLY—6, 8, 8; ALA—28, 30, 30; VAL—20, 18, 18, and HIS—4, 4, 6. The discovery of additional genetic variants of β-lactoglobulins should be allowed for.

α-Lactalbumin, the protein of second greatest concentration in whey, has been found to exist in the form of two genetic variants, A and B, in the milks of Zebu cattle (3, 9, 11). There is no variation from the B-form in the milk of Western breeds. The locus symbols $\alpha\text{-La}^A$ and $\alpha\text{-La}^B$ have been assigned to these proteins, of which to date only the B-variant has been characterized in any detail. Table 1 summarizes some of the properties of the more thoroughly characterized proteins of whey.

It is not within the scope of this Committee's responsibility to deal with all the enzymes and minor proteins found in cow's milk. More recent discoveries of milk proteins, however, seem desirable to include in this report. The enzyme ribonuclease has been found in cow's milk in a concentration of approximately 32 mg/liter (10). The enzyme may be prepared conveniently by chromatography of whey on IRC-50 in the ammonium form. Gordon et al. (18a) and Groves (21) have reported the purification of a red protein and of a new crystalline protein, which they have named lactollin, from cow's milk. Both proteins, characterized by electrophoresis and amino acid composition, are basic proteins. The red protein may be distinguished from lactollin by its higher carbohydrate content. Lactollin, unlike the red protein, does not bind iron.

The first report of the Committee (31) called attention to the fact that the proteose-peptone fraction has not been satisfactorily resolved. Jenness (29, 30) has reported the isolation and properties of Milk Component 5, which is believed to represent part of the proteose-peptone fraction of Rowland (56), (see also 24, 25) and to be similar to the sigma-proteose fraction of Aschaffenburg and Ogston (6). Brunner and Thompson (13), after comparing several of the above fractions, concluded that chemical and physical similarities existed among them. The differences among these fractions are probably a reflection of the method of preparation. Because Milk Component 5 is a phosphoprotein, some question exists as to its classification—a casein or a whey protein? Until this protein is adequately characterized, the Committee reserves judgment regarding the acceptability of the term proteose-peptone, but continues to include the term in the nomenclature (Table 1).

Caseins. (See Glossary of Terms for definitions of casein components or fractions, or both). *β-Casein.* This protein, second only in concentration to α_s-casein in cow's milk, has been the object of comparatively little research, though it is one of the most remarkable of the casein fractions. We define a β-casein as that fraction of casein soluble in 3.3 M urea, but insoluble in 1.7 M urea at pH 4.6 (27). Furthermore, it is that casein which undergoes temperature dependent molecular association. At 4 C β-casein is monomeric, at 8.5 C concentration-dependent aggregation is observed (50, 59, 75) and at 20 C it is completely polymeric. β-Casein is insensitive to calcium ions at low temperature, but is aggregated by them at 35 C. Three principal methods for its isolation have been reported (4, 27, 77). Further purification can be accomplished by DEAE-cellulose chromatography in the presence of urea (16, 70) by the method of Ribadeau-Dumas (53).

Recent physical investigations by Payens and Van Markwijk (50), as well as those by Nielsen and Lillevik (48), have given a molecular weight of the order of 25,000 for β-casein. The genetic variant upon which these studies were performed was not defined, but was presumably β-A. Zittle and Walter (83) have shown that β-casein, like α_s-, enters into micelle formation with κ-casein in the presence of cal-

TABLE 1

Protein fractions of cow's skimmilk and some of their properties

Protein fraction									
Classical nomenclature [a]	Contemporary nomenclature	Occurrence in electrophoretic pattern [b] (Peak no.)	Reference to preparation	Approximate per cent of skimmilk protein [c]	Sedimentation constant [d] (S_{20})	Molecular weight [e]	pI [f]	Electrophoretic mobility at pH 8.6 [g]	Other characteristics
Casein (precipitated from skimmilk by acid at pH 4.6)		In casein pattern	27, 77	76–86	1.18 (75) [i]	15,000 (75) 33,600 (14)			
	α-casein	1	27, 77	45–63	3.99 (59)	27,000 (48)	4.1 (31)	−6.7 (31)	Contains 1% phosphorus. Consists of a mixture of proteins (see Table 4). Formed in the udder[n].
	β-casein	2	27, 77	19–28	1.57 (59)	24,100 (59)	4.5 (31)	−3.1 (31)	0.6% Phosphorus. Formed in udder.
	γ-casein	3	27	3–7	1.55 (46)	30,600 (46)	5.8–6.0 (31)	−2.0 (31)	0.1% Phosphorus. Preformed from blood.
Noncasein proteins		In acid whey pattern		14–24					
Lactalbumin (Soluble in ½ saturated $(NH_4)_2SO_4$ soln.)	β-Lactoglobulin A	6	5	.....	2.8 (73) [i] 5.3 (73) [j]	36,000 (72) [o]	5.20	−5.3	Associates in pH range 3.7 to 5.3. Formed in udder.
	β-Lactoglobulin B (Mixed A and B)	6	5	7–12 [h]	2.7 (73)	36,000 (72) [o]	5.30	−5.2	Exists principally in monomeric form. Formed in udder.
	β-Lactoglobulin C	6	74	.....	2.7 (74)	36,000 (74)	5.33		Exists principally in monomeric form. Formed in udder.
	α-Lactalbumin (B-form)	4	19, 20	2–5	1.75 (19)	16,500 (19)	5.1 (35) [i]	−4.2 (19) [m]	7% Tryptophan. Formed in udder.
	Blood serum albumin	7	52	0.7–1.3	4.0 (15)	69,000 (52)	4.7 (52)	−6.7 (52)	Apparently identical to bovine serum albumin. Preformed from blood.

TABLE 1 (Concluded)

Protein fraction									
Classical nomenclature [a]	Contemporary nomenclature	Occurrence in electrophoretic pattern [b] (Peak no.)	Reference to preparation	Approximate per cent of skimmilk protein [c]	Sedimentation constant [d] (S_{20})	Molecular weight [e]	pI [f]	Electrophoretic mobility at pH 8.6 [g]	Other characteristics
Lactoglobulin (insoluble in ½ saturated $(NH_4)_2SO_4$ soln.)	Euglobulin	1	58	0.8–1.7	8.77 (46) [k]	252,000 (46) [k] 180,000 (58) [k]	6.0 (46)	−1.8 (46)	Fractions containing antibodies. Contain hexose and hexosamine. Electrophoretically and ultracentrifugally heterogeneous. Preformed from blood.
	Pseudoglobulin	2	58	0.6–1.4	8.07 (46) [k]	289,000 (46) [k] 180,000 (58) [k]	5.6 (46)	−2.0 (46)	
Proteose peptone fraction (not precipitated at pH 4.6 from skimmilk previously heated to 95-100 C, 30 min)			6, 31, 39	2–6	0.96 (6) [k] 2.75 (6)	4,900 (6) [k] 24,900 (6)			Glycoprotein (63). Electrophoretically and ultracentrifugally heterogeneous. Poorly defined except for Whey Component 5 (30).
		3						−3.0 (39)	
		5			1.0			−4.6 (39) [k]	
		8						−7.9 (39)	

[a] Rowland fractions (56).

[b] Free-boundary electrophoresis in veronal buffer at pH 8.6, $\Gamma/2 = 0.1$. Casein components designated in descending order of mobility. Whey protein components designated in ascending order of mobility (39).

[c] Values for the major groupings compiled or calculated from Rowland nitrogen distribution data (56) and for the subgroups from relative area of electrophoretic patterns obtained on milks from individual cows of various breeds (38, 54).

[d] S_{20} = sedimentation coefficient = $(dx/dt)\ (\omega^2 x)$, in Svedberg units ($S = 1 \times 10^{-13}$) corrected to 20 C. See original literature for experimental conditions. Sedimentation characteristics are dependent upon ionic strength of solvent, temperature, pH, and concentration of solute. The sedimentation and molecular weight values reported are not necessarily the best values obtainable, nor do they constitute endorsement by the Committee.

[e] Refer to original literature for method and conditions of determination.

[f] Isoelectric point, i.e., pH of no electrophoretic migration.

[g] Electrophoretic mobility (μ) = $\times 10^{-5}$ cm^2 volts^{-1} sec^{-1} obtained by the Tiselius moving boundary method at 2 C in veronal buffer at pH 8.6, $\Gamma/2 = 0.1$. Measured from descending pattern.

[h] Distributions of β-lactoglobulin A, B, and C are genetically determined (5, 8).

[i] Denotes the characteristic of the monomeric species.

[j] Denotes the characteristic of the associated species.

[k] Denotes the characteristics of the major component.

[l] Value replaces previously reported value of 4.1 to 4.8.

[m] Mobility reported at −3.6 in milk serum protein mixture (37).

[n] Source of information pertaining to the origin of the milk proteins (36).

[o] Mean value taken from physical measurements.

cium. The role of β-casein(s) in the formation of native casein micelles needs further study.

Aschaffenburg (1, 2) has contributed significantly to an understanding of the genetic heterogeneity of β-casein. By paper electrophoresis, 6.0 M urea, pH 7.15, he showed that individual cows produced three forms either singly (A, B, or C) or in pairs (AB, AC, or BC). He assigned the locus symbol, β-Cn, to these caseins. Thompson et al. (66) have confirmed these findings. The studies (Table 2)

TABLE 2

Breed differences in the production of α_{s1}- and β-casein variants

Breed	α_{s1}-Casein (34)	β-Casein (2, 66)
Holstein	A, B, C	A, B
Guernsey	B, C	A, B, C
Jersey	B, C	A, B
Brown Swiss	B, C	A, B, C
Ayrshire	B	A
Shorthorn [a]	B	A

[a] Aschaffenburg, personal communication.

show that the occurrence of the genetic forms of β-casein is breed-specific, and that the gene frequencies of β-A, B, and C differ widely among breeds. Some chemical differences among the three genetic variants are presented in Table 3. Present studies concerning end group analyses, amino acid differences, and physical behavior will provide additional criteria for future identification of these proteins. At the present, however, this Committee feels that the variants can be correctly identified by appropriate electrophoretic techniques such as starch-gel electrophoresis (SGE), polyacrylamide-gel electrophoresis (PAE), or paper electrophoresis. Assignment of relative mobilities in either starch-gel or polyacrylamide-gel is especially useful in identifying the β-caseins. A summary of the relative mobilities of β-caseins in such gels is given in Table 5. The Committee regards the nomenclature of β-caseins in terms of genetic variants as appropriate. Therefore, the β-caseins are termed β-casein A, β-casein B, and β-casein C. For more precise identification the relative mobilities should be quoted, e.g., β-casein A (0.80) by SGE, or β-casein A (0.65) by PAE. This system is sufficiently flexible to allow for the inclusion of additional β-casein variants differing in net negative charge. For example, a new variant found to migrate between A and B on SGE with a relative mobility of 0.78 would be termed β-casein D (0.78).

α-Casein complex. The calcium-sensitive α-caseins. The calcium-sensitive fraction of the α-casein complex is one of the most difficult fractions of the casein complex to define. Waugh (78) termed this fraction α_s-casein and later referred to it as $\alpha_{s1,2}$ (79). Calcium-sensitive α-casein has also been termed α_1- (45), α_R- (41), and α-caseins 1.07 and 1.10 (57). The properties and comparisons of some of these proteins have been previously reviewed by Brunner et al. (12), Lindqvist (40), and Thompson and Kiddy (65). They will not be discussed in great detail in this text, but a summary of some of their properties appears in Table 4. A major breakthrough in studying the heterogeneity of the α-casein complex occurred in 1962, when Thompson et al. (67, 68) reported the discovery of three genetic forms of α_s-casein, which differed only slightly in their mobility on SGE. These caseins, which occur singly (A, B, or C) or in pairs (AB, AC, or BC), are produced in a straightforward Mendelian manner, and parallel β-casein in this respect. Kiddy et al. (34), in keeping with the proposal of Aschaffenburg (1), have ascribed the locus symbol, α_s-Cn, to these caseins. The occurrence of the three forms of α_s-casein, like that of the β-casein (Table 2), has been found to vary from breed to breed, Ayrshires, for example, producing only the B form. Thompson and Pepper (69) and Thompson and Kiddy (65) have isolated and character-

TABLE 3

Some properties of β-casein fractions

Fraction	Reference to preparation	Nitrogen	Phosphorus	P/N ratio	$A^{1\,cm}_{1\%}$ [b]
		(%)			
β-A	(70)	15.18	0.59	0.0389	4.6
β-B	(70)	15.33	0.57	0.0372	4.7
β-C	(70)	15.45	0.50 (0.52) [a]	0.0324	4.5
β-Casein	(27)	15.47	0.64	0.0414	....
β-Casein	(23)	15.35	0.48	0.0313	

[a] Sample supplied by R. Aschaffenburg.
[b] 280 mμ wavelength.

TABLE 4

Some properties of reported components of the complex α-casein

α-Casein	Ref. to preparation	Nitrogen (%)	Phosphorus (%)	S_{20}	$A^{1\,cm}_{1\%}$	pI	End groups C	End groups N	Molecular weight
Ca-sensitive components									
α_{s1}-A casein	(65)	15.10	1.01	.....	10.10	....	Try	Arg	~30,000 [c]
α_{s1}-B casein	(65)	15.34	1.01	.....	10.05	....	Try	Arg	~30,000 [c]
α_{s1}-C casein	(65)	15.40	1.01	.....	10.03	....	Try	Arg	~30,000 [c]
α_s	(82)	15.10	1.01	.....	10.20	4.4	.....	.....	.....
α-Caseins (1.07 and 1.10)	(57)	14.00	1.12	1.64 [b]	.....	....	.....	Arg	16,500
$\alpha_{s1,\,2}$-Casein	(79)	14.70	1.03		10.1	....	Try-leu-tyr	.....	27,500
α_R-Casein	(41)	.....	1.18	4.55 [a]	.....	....	.....	.....	.....
α_1-Casein	(45)	14.10	0.85	3.00 [a]	.....	4.3–4.7	.....	.....	.....
Ca-insensitive components									
κ-Casein	(80)	.....	0.19	1.40 [b]	.....	....	.....	.....	16,300
				13.50 [a]	.....	....	.....	.....	.....
κ-Casein	(44)	.....	.....	13.60 [a]	.....	....	.....	.....	.....
κ-Casein	(60)	13.5	0.35	12.90 [a]	.....	3.8–4.2	.....	.....	~24,000 (60) 60,000 (61)
κ-Casein	(82)	15.4	0.30	.....	12.2	3.7	.....	.....	.....
α_3-Casein	(28)	14.6	0.35	23.10 [a]	15.6	5.0	.....	.....	.....
λ-Casein	(41)	.....	1.18	1.10	.....	....	.....	.....	.....
mμ-Casein	(78)	.....	.....	.....			.....	.....	.....

[a] Denotes characteristics of associated form.
[b] Denotes characteristics of monomer form.
[c] Minimum molecular weights deduced from amino acid analyses (17) and end group analyses (32).

TABLE 5

Relative mobilities of α_{s1}- and β-casein variants by starch-gel and polyacrylamide-gel electrophoresis

Variant	SGE (65)	PAE (70)
α_{s1}-A	1.18	1.22
α_{s1}-B	1.10	1.13–1.14
α_{s1}-C	1.07	1.10
(?)	1.04	~1.03
Reference zone [a]	1.00	1.00
(?)	0.86	~0.72
β-A	0.80	0.65
β-B	0.76	0.61
β-C	0.70	0.54

[a] Using the zone reference system of Wake and Baldwin (76).

ized the three forms of α_s-casein and compared them with previously reported calcium-sensitive α-casein preparations (Table 4).

A nomenclature scheme which will embrace all of these reported calcium-sensitive α-caseins, and one which will include newly isolated components, is difficult to formulate. In deliberating this question, the Committee considered the following: (a) Many of the reported α-casein fractions appear to be identical except for purity. Manson (42), Schmidt and Payens (57), and Kalan et al. (32) showed, for example, that their respective calcium-sensitive α-casein preparations contained N-terminal arginine. (b) An operational definition for calcium-sensitive α-caseins, such as the one proposed by Waugh et al. (79), and the one which appears satisfactory for β-caseins, seems desirable. That α_s-caseins are sensitive to calcium ions and are stabilized by κ-casein against precipitation with calcium has been well established (65, 82). However, the formation of stoichiometric complexes (3:1 weight ratio) of α_s:κ is in doubt (16a). A more satisfactory operational definition must await more conclusive research. (c) In addition to the components mentioned above, several other α_s-like caseins exist (79), e.g., Wake and Baldwin's (76) zones 1.04 and 1.00 which are stabilized by κ-casein against precipitation with calcium. The nomenclature must include these components. (d) SGE, as described by Wake and Baldwin (76) and PAE (65), are discriminating methods for identification of casein components by their relative electrophoretic mobility. (e) The term α_s is descriptive and succinct in defining that fraction of α-casein precipitated by calcium ions at 0-4 C, and which is stabilized by κ-casein in the presence of these ions.

This Committee recommends that in the future the genetic variants (A, B, and C) of the principal α_s-casein fraction be referred to as α_{s1}-A, α_{s1}-B, and α_{s1}-C. A statement of the relative electrophoretic mobility value for each

variant (Table 5) should accompany the genetic designations for purposes of identification.

α_{s1}-A	(1.18)
α_{s1}-B	(1.10)
α_{s1}-C	(1.07)

Such a system is sufficiently flexible to allow for the discovery of additional genetic variants, e.g., a variant of the α_{s1}-series may be discovered with a relative mobility of 1.14. It would be termed α_{s1}-D (1.14). The naming of other α_s-like caseins would be prescribed in (a) chronological order of characterization and (b) relative mobility on SGE or PAE. Zones 1.04 and 1.00 might be termed α_{s2} (1.04) and α_{s3} (1.00), respectively. To date, no genetic variants of these components have been observed. Figure 1 demonstrates the naming of casein by relative position on starch-gel electrophoresis (7.0 M urea) according to the method of Wake and Baldwin (76). Although a considerable amount of information is available concerning the α_s-caseins, more particular information, such as detailed amino acid composition (17, 62, 71) and physical properties of the components, is needed.

Calcium-insensitive caseins. In 1956 Waugh and von Hippel (80) reported the isolation of a calcium-soluble casein capable of stabilizing α_s-casein against precipitation with calcium. This low phosphorus-containing casein was termed κ-casein and has since been the object of much research. κ-Casein is attacked by rennin in the primary reaction; an insoluble disulfide-containing fraction (para-κ-casein) and a soluble carbohydrate-containing fraction (glyco-macropeptide) are released. At pH 7.0, $\Gamma/2 = 0.20$, in the ultracentrifuge κ-casein sediments as a polymer (S_{20} ~13 of unknown number of monomers) whereas at pH 12.0 the monomeric species is observed. According to Swaisgood and Brunner (61) κ-casein consists of a basic unit of ~60,000 molecular weight. Following reduction of disulfide bonds, they observed a molecular weight (Z-average) of about 20,000 and thereby concluded that κ-casein consists of two or more polypeptide chains which are crosslinked by disulfide.

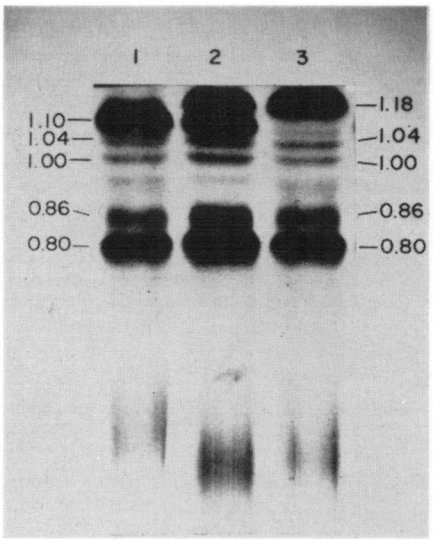

FIG. 1. Starch-gel electrophoresis patterns showing a portion of the zone-numbering system of Wake and Baldwin (76). Pattern 1 is α_{s1}-B, typed whole casein; 2, α_{s1}-AB; α_{s1}-A.

Numerous methods for the preparation of κ-casein have been suggested (26, 44, 60, 80, 82). Most of them make use of the solubility of κ-casein in dilute $CaCl_2$ (44). Novel fractionation methods involving the solubility of κ-casein in 6.6 M urea and strong acids, 12% TCA (60), or H_2SO_4 (82) have been described. DEAE-cellulose column chromatography has been employed in the purification of κ-casein (55). The κ-casein preparations isolated by the various methods have been found to vary in elemental composition (Table 4) and in physical behavior. They have also been found to vary in sialic acid content (43). These discrepancies are explicable on the basis of variations in purity or method of preparation, or both.

Electrophoresis of κ-casein on starch-gel, in 7.0 M urea, normally yields a smeared, poorly defined zone of migration. Neelin (47) observed that reduction of the disulfide bonds of κ-casein resulted in formation of definite zones, moving more slowly than β-casein. Examination of the milks of individual cows demonstrated differences in the κ-casein fraction, which was evidence of genetic heterogeneity. Woychik (81), using polyacrylamide-gel electrophoresis, observed almost identical phenomena. These preliminary results suggest that κ-casein, like α_{s1}- and β-caseins, is genetically variable. If established, the Committee recommends that the genetic variants of κ-casein be termed: κ-A, κ-B, κ-C, etc., in order of decreasing electrophoretic mobility, a proposal consistent with the genetic designation of α_{s1}- and β-caseins.

In addition to κ-casein, other so far ill-defined components are found in the calcium-soluble α-complex. These fractions of high phosphorus content (1.2%) have been termed λ (41) and m-caseins (78). Until better characterized, the Committee has no recommendations to propose regarding their nomenclature.

Concluding remarks. This Committee has given particular attention to recent discoveries concerning genetic variations of milk proteins. These discoveries have been particularly valuable in establishing a more adequate nomenclature system. The usefulness of this system will depend on the ease with which various laboratories can apply established methods, such as starch-gel and polyacrylamide-gel electrophoresis in detecting genetic heterogeneity in the caseins. To observe the ease with which this could be accomplished, Thompson (63a) supplied the six phenotypes each of α_{s1}- and β-caseins to six laboratories. Eight unknown casein samples were also supplied, and the laboratories requested to type α_{s1}- and β-caseins by their own preferred zonal electrophoresis methods. With the exception of one phenotype, all of the laboratories identified the samples correctly. These results serve as a confidence factor to the nomenclature scheme.

The deliberations of this Committee regarding the inclusion of genetic terminology in the nomenclature have been concerned with proteins which differ in electrophoretic mobility. However, genetic variants may be found in the future in which neutral amino acids have been substituted within the polypeptide chain or where subtle differences in amino acid composition are not revealed by present electrophoretic techniques. As methodology progresses, subsequent Committees may be faced with the task of indicating genetic differences in milk protein molecules by citing specific amino acid additions, deletions or substitutions. Clearly, the nomenclature now proposed would require modification.

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GLOSSARY OF TERMS FOR THE CASEINS

Whole casein. A heterogeneous group of phosphoproteins precipitated from skimmilk at pH 4.6 and 20 C.

α-Casein complex. A fraction of whole casein containing α_s-, κ-, and λ-caseins, soluble in 6.6 M urea, but insoluble in 4.6 M urea (27).

α_s-Caseins. A fraction of the α-casein complex insoluble in 0.40 M $CaCl_2$ at pH 7.0 and 0-4 C. This fraction includes the genetically variable α_{s1}-caseins and other α_s-like caseins. α_s-Caseins are stabilized by κ-casein against precipitation with calcium.

α_{s1}-Caseins. These components are stabilized by κ-casein against precipitation with calcium, and constitute the greater portion of the total α_s-casein fraction. Three genetic forms (A, B, and C) of these caseins have been observed in the milks of individual cows.

α_s-like caseins. These caseins include those calcium-sensitive components of the α-casein complex, other than α_{s1}-A, B, and C, which are stabilized by κ-casein against precipitation with calcium ions. These caseins are not adequately characterized.

β-Casein. A fraction of whole casein soluble in 4.6 M urea but insoluble in 3.3 M urea at pH 4.6. β-Caseins are precipitated with calcium at 35 C, but not at 4 C, and possess ultracentrifugal association-dissociation properties which are pronounced at 8.5 C. Three genetically variable forms (A, B, and C) have been observed in milk of individual cows.

κ-Casein. A fraction of the α-casein complex soluble in 0.40 M $CaCl_2$ at pH 7.0 and 0-4 C. This phospho-glyco-protein is capable of stabilizing α_s-caseins against precipitation with calcium, and appears highly aggregated (S_{20} ~13) in the ultracentrifuge at pH 7.0 and $\Gamma/2 = 0.20$. κ-Casein is the principal casein affected by rennin in the primary phase of rennin action; insoluble para-κ-casein and soluble glyco-macropeptide are formed.

λ-Casein. An ill-defined fraction of the α-casein complex soluble in 0.40 M calcium at pH 7.0 and 0-4 C. This heterogeneous high phosphorus (1.2%) fraction does not stabilize α_s-caseins against precipitation with calcium. Its low S_{20} (~1) in the ultracentrifuge at pH 7.0 and $\Gamma/2 = 0.20$ suggests it to be in the monomeric form.

γ-Casein. A fraction of whole casein soluble in 3.3 M urea but insoluble in 1.7 M urea at pH 4.7 upon the addition of $(NH_4)_2SO_4$.

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