Aula 4

Os microrganismos como agentes alteração

Factores condicionantes da dinâmica de populações mistas

Conservação de alimentos

Table 2 Major consumer trends having an impact on future food preservation technologies

Consumers will require products that are:
Convenient
easy to store
satisfactory shelf-life
High quality
Less severely processed
less intensively heated
minimally freeze-damaged
Less heavily preserved
Freer from 'artificial additives'
Fresher
More natural
Nutritionally healthier, with
lower salt
lower fat
less saturated fats
more unsaturated fats
lower sugar
lower calorie
Safer

Definição de alteração

- Diminuição da qualidade, de forma a tornar o alimento inaceitável
  - Crescimento microbiano à superfície ou em suspensão
  - Perda de textura
  - Gás, pigmentos, polissacáridos, cheiros e sabores desagradáveis (mais frequentes)
- Subjectividade cultural
- Tipos: glicolítica, proteolítica e lipolítica

Tempo de prateleira

- Qualidade aceitável (sem alteração que implique rejeição pelo consumidor)
- Seguro (do ponto de vista microbiológico, físico e químico)

IMPORTANCE ACCORDING TO THEIR INCREASING INTRINSIC RESISTANCE TO COLONIZATION, BASED ON ADHERENCE TO CUSTOMARY GOOD MANUFACTURING AND DISTRIBUTION PRACTICES

Microbial growth potential	Examples
Unlimited	Fresh, chilled meat, poultry and seafood
Ample	Pasteurized milk, refrigerated undamaged fruits and vegetables
Limited	Cooked sausage in intact casing, refrigerated
Restricted	Vinegar-preserved and fermented foods, commodities with $a_w < 0.90$
	Frozen foods
Virtually absent	Appertized foods
	Foods dried to $a_w < 0.60$

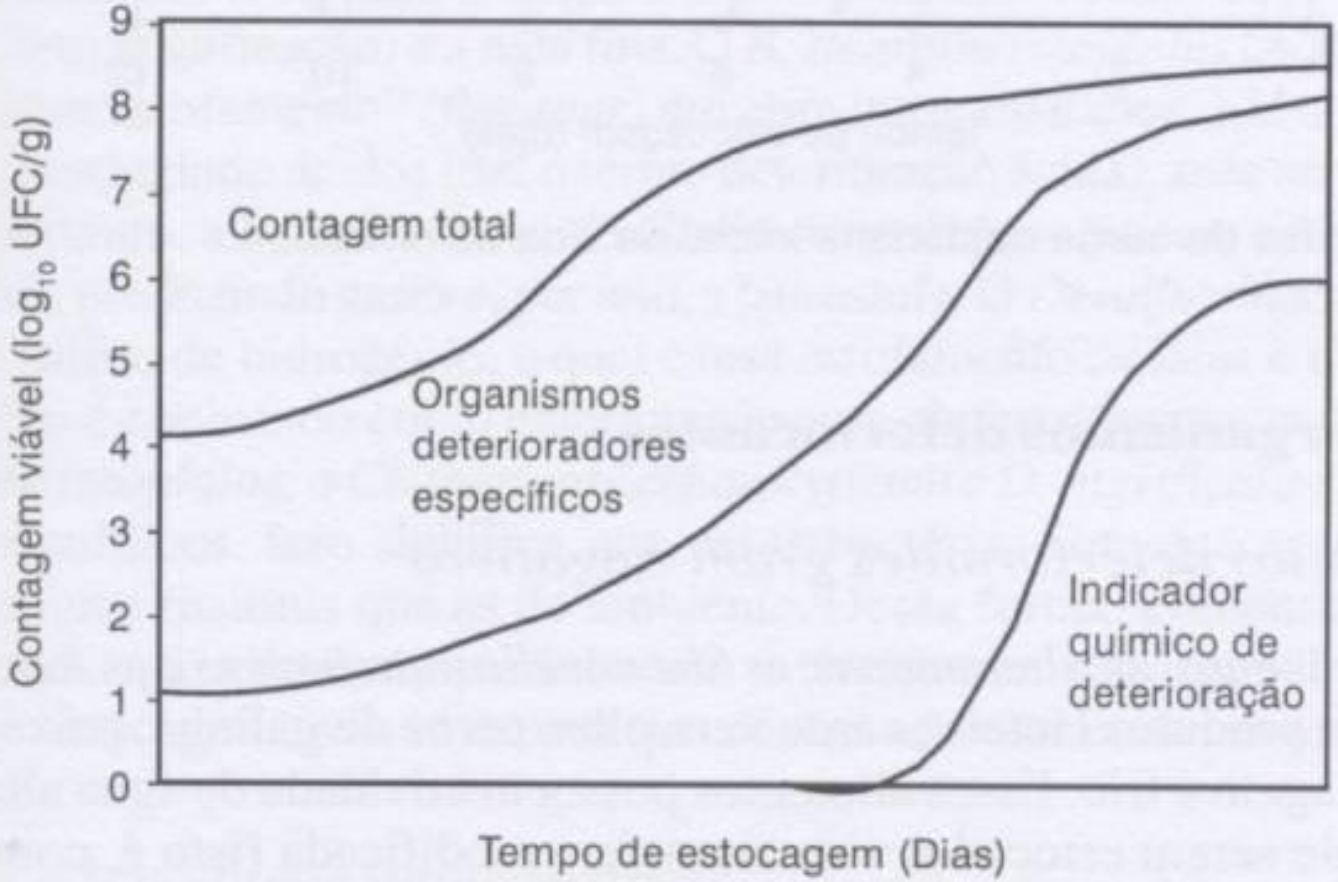


Figura 4.2 Indicadores de deterioração de alimentos.

Forsythe (2000)

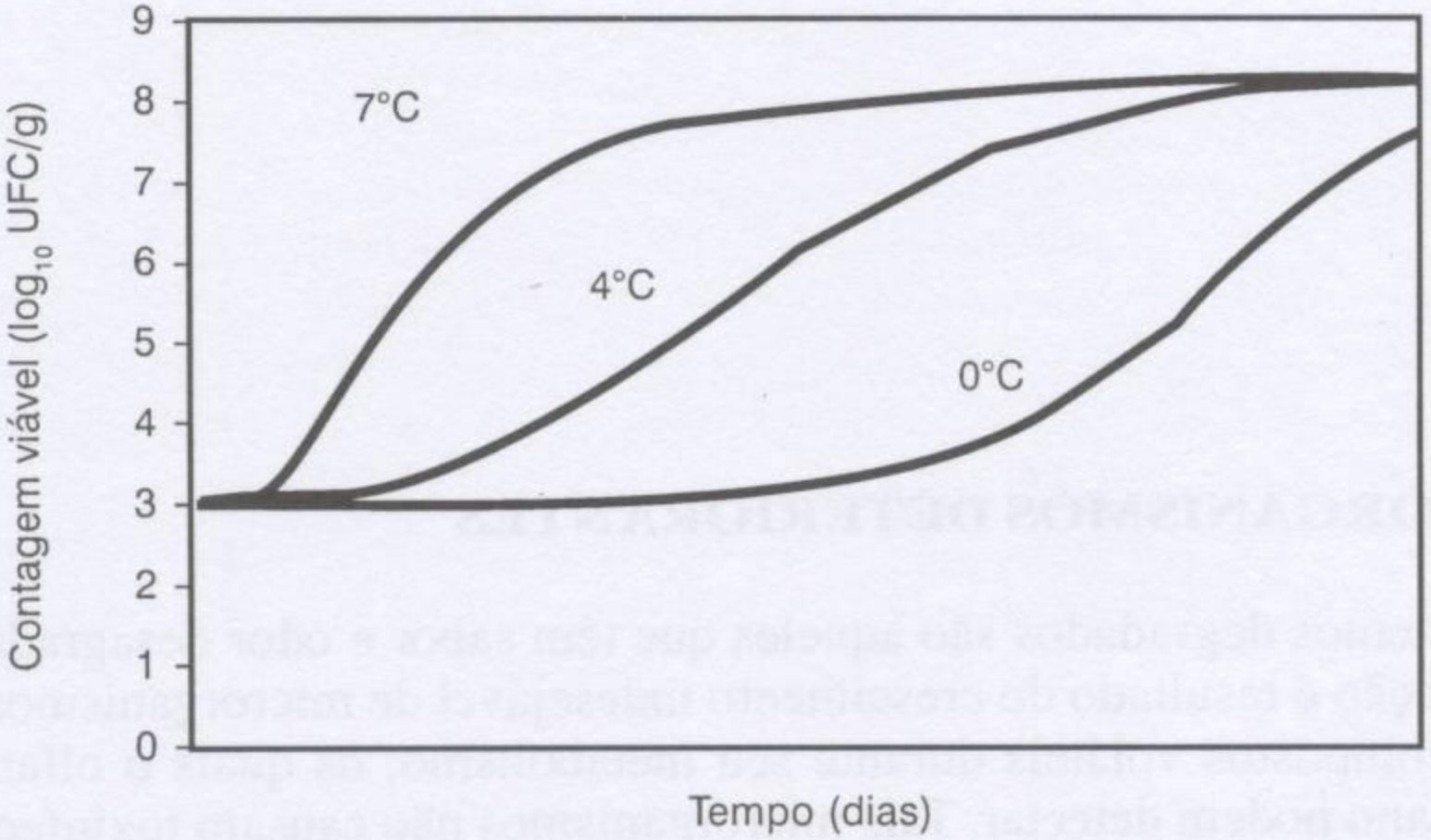


Figura 4.1 Efeito da temperatura na deterioração dos alimentos.

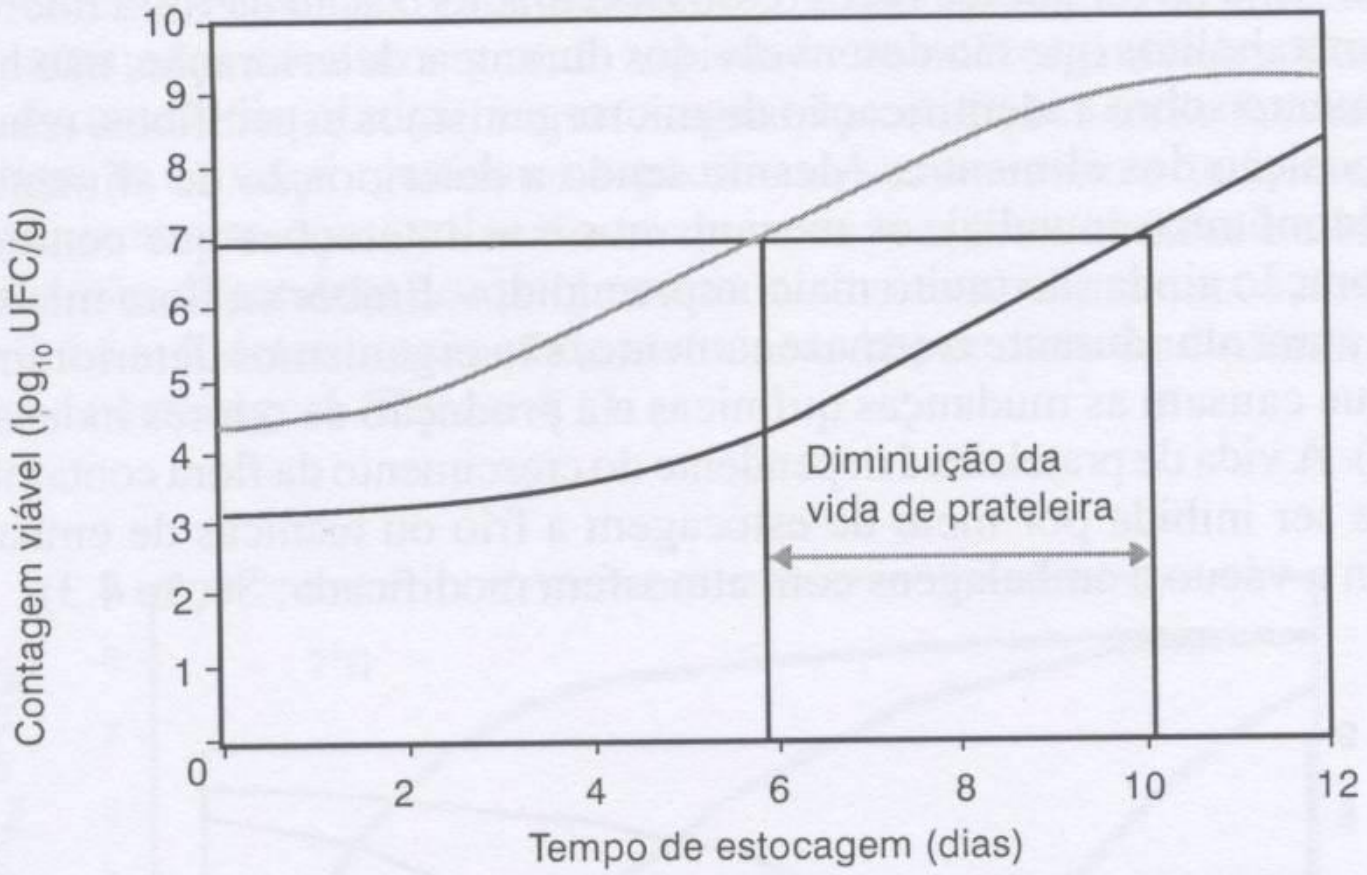


Figura 4.3 Efeitos da carga bacteriana inicial na vida de prateleira.

Tabela 4.3 Produtos alimentícios e seus tempos de prateleira

Produtos alimentícios	Vida de prateleira esperada
Pão	Até 1 semana à temperatura ambiente
Molhos, temperos	1 a 2 anos à temperatura ambiente
Pepino	2 a 3 anos à temperatura ambiente
Alimentos resfriados	Até 4 meses entre 0 e 8°C
Alimentos congelados	12 a 18 meses no congelador
Alimentos enlatados	Latas não-envernizadas, 12 a 18 meses Latas envernizadas, 2 a 4 anos

Factores que afectam o desenvolvimento das associações microbianas nos alimentos

Factores intrínsecos	**Nutrientes**
	pH e poder tampão
	Potencial Redox
	Actividade da água
	Constituintes antimicrobianos
	Estruturas antimicrobianas
Factores ambientais	**Humidade relativa**
	Temperatura
	Atmosfera
Factores implícitos	**Taxa específica de crescimento**
	Mutualismo
	Antagonismo
	Comensalismo
Factores de processamento	**Fraccionamento**
	Lavagem
	Embalagem
	Irradiação
	Pasteurização

Adams e Moss (2000)

Table 1 Major factors affecting the microbial ecology of foods

Intrinsic factors					
Chemical	Physical	Processing factors	Extrinsic factors	Implicit and microbial factors	Net effects
Nutrients present	Water activity	Changes in types of micro-organisms	Temperature	Micro-organisms present	Interactions between factors—'combination' and 'hurdle' effects
Nature of solutes	Ice and effects of freeze-concentration	Changes in numbers of micro-organisms	Relative humidity	Microbial lag times and growth rates	
pH and buffering capacity	Viscosity	Changes in food composition	Oxygen partial pressure	Synergistic effects	
Oxidation-reduction potential	Microstructure	Changes in food microstructure	Presence of other gases	Antagonistic effects	
Presence of preservatives and other antimicrobial substances	Compartmentalization				

Adapted from Mossel & Ingram (1955) and Mossel (1983).

Factores intrínsecos

- Nutrientes
- pH e capacidade tampão
- Potencial redox
- Actividade da água (a_w)
- Estruturas antimicrobianas
- Constituintes antimicrobianos

Table 3.2 *Approximate pH ranges of some common food commodities*

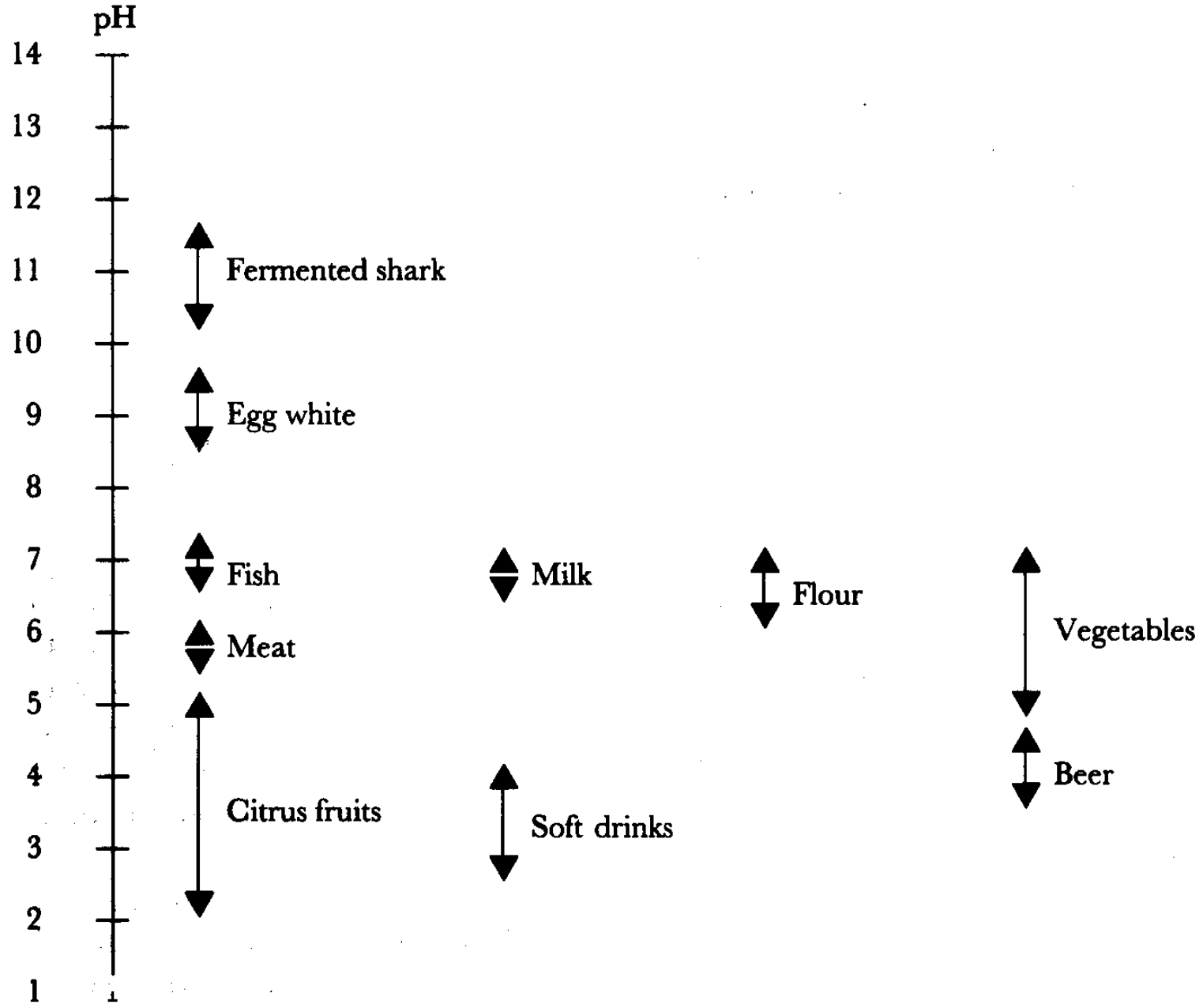


TABLE 3.5. APPROXIMATE LIMITING VALUES OF pH[a] FOR MICROBIAL GROWTH

Organisms	Min.	Max.
1. Normoduric bacteria		
Gram-negative rods	4.5–6	8–9
Gram-positive cocci		
Gram-positive sporing rods		
2. Aciduric bacteria		
Acetobacter spp.		
Lactobacillus spp.	3–4	5–9
Lancefield group N streptococci		
Clostridium butyricum, *Bacillus coagulans*		
3. Alkali-tolerant bacteria		
Genus *Vibrio*	5	11
4. Moulds and yeasts	2–5	7–11

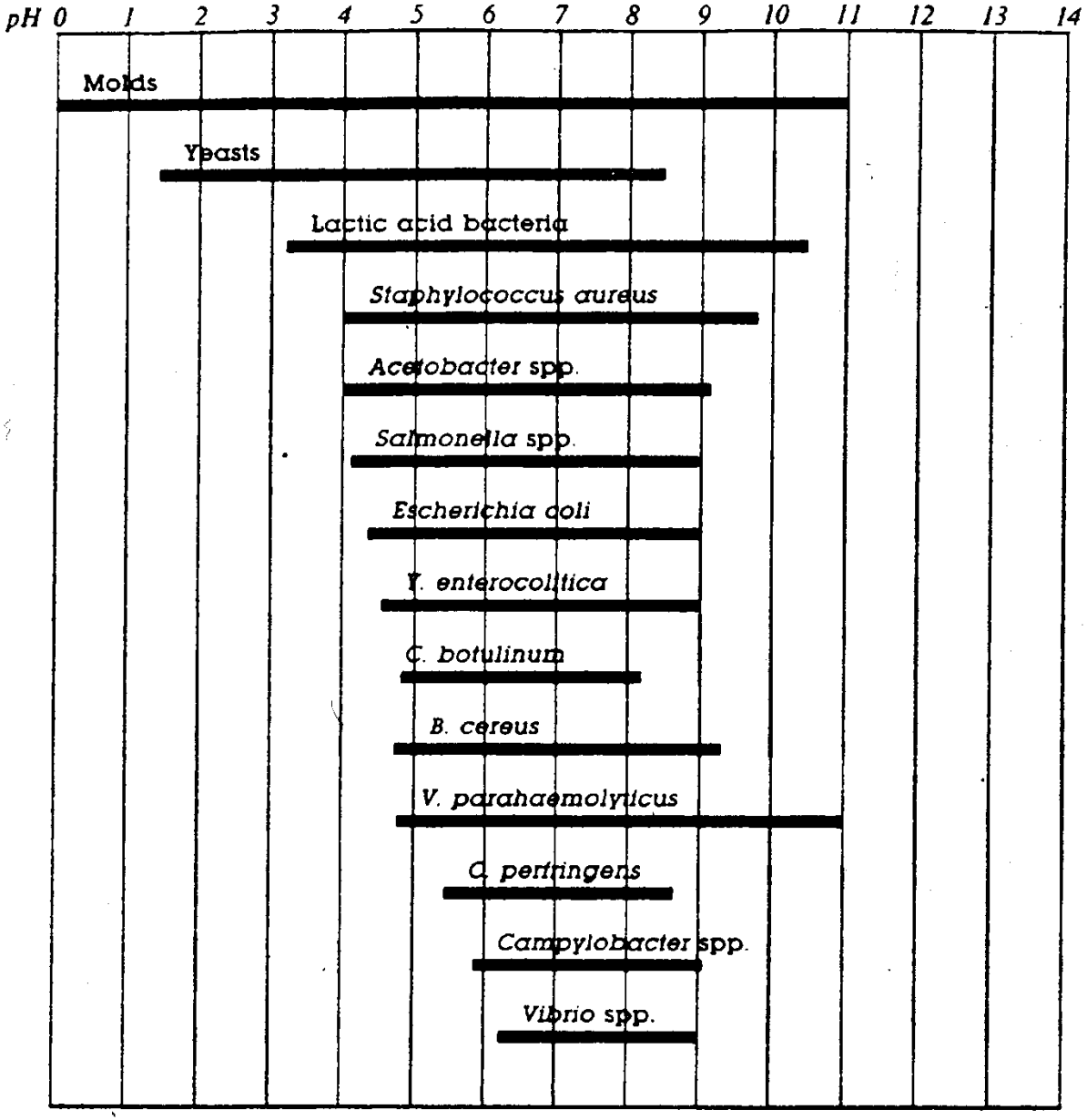


Figure 3.1. Approximate pH growth ranges for some foodborne organisms.

Actividade da água

Aw = P / P0 = 1/100 ERH

P, pressão parcial da água na atmosfera em equílibrio com o alimento
P0, pressão parcial da água pura
ERH, humidade relativa de equílibrio

Aw= Nág / (Nág+Nsol)

É uma propriedade coligativa: depende d nº de moléculas e não do seu tamanho

LATO SENSU PÓS-COLHEITA

Teor de Água de Equilíbrio

O conceito Teor de Água de Equilíbrio é importante para A SECAGEM e ARMAZENAGEM dos produtos. Indica se o produto ganhará ou perderá umidade, segundo as condições de temperatura e umidade relativa do ar utilizado na operação.

Teor de Água de Equilíbrio = Equilíbrio Higroscópico.

TAeq. = f(T, UR, das condições físicas dos grãos) e



Possuem TEORES DE ÁGUA DE EQUILÍBRIO diferentes

Próximo

TIPO DE SEMENTE	TEMPERATURA °C	UMIDADE RELATIVA DO AR (%)								
		10	20	30	40	50	60	70	80	90
ARROZ	15	4,9	7,6	9,3	10,5	11,5	12,6	13,8	15,6	18,0
	25	4,8	7,3	8,9	10,1	11,1	12,1	13,3	15,0	17,4
	35	4,6	7,0	8,5	9,7	10,6	11,6	12,8	14,5	16,7
MILHO	15	5,5	7,8	9,2	10,2	11,3	12,7	14,3	16,6	19,8
	25	4,8	7,0	8,4	9,4	10,5	11,8	13,4	15,5	18,5
	35	4,3	6,4	7,7	8,7	9,8	11,0	12,5	14,5	17,3
SOJA	15	4,3	5,7	6,5	7,2	8,1	10,1	12,4	16,1	21,9
	25	3,8	5,3	6,1	6,9	7,8	9,7	12,1	15,8	21,3
	35	3,5	4,8	5,7	6,4	7,6	9,3	11,7	15,4	20,6
TRIGO	15	5,5	7,7	9,1	10,4	11,6	12,8	13,9	15,6	18,2
	25	5,0	6,9	8,2	9,5	10,7	12,0	13,2	14,9	17,4
	35	4,6	6,3	7,4	8,6	9,9	11,2	12,5	14,2	16,7

TABELA 2.
UMIDADE EM EQUILÍBRIO COM A UMIDADE RELATIVA DO AR DE DIFERENTES TIPOS DE SEMENTES À DIFERENTES TEMPERATURAS.

Table 3.9 *Minimum water activities at which active growth can occur*

Group of micro-organism	*Minimum* a_w
Most Gram-negative bacteria	0.97
Most Gram-positive bacteria	0.90
Most yeasts	0.88
Most filamentous fungi	0.80
Halophilic bacteria	0.75
Xerophilic fungi	0.61

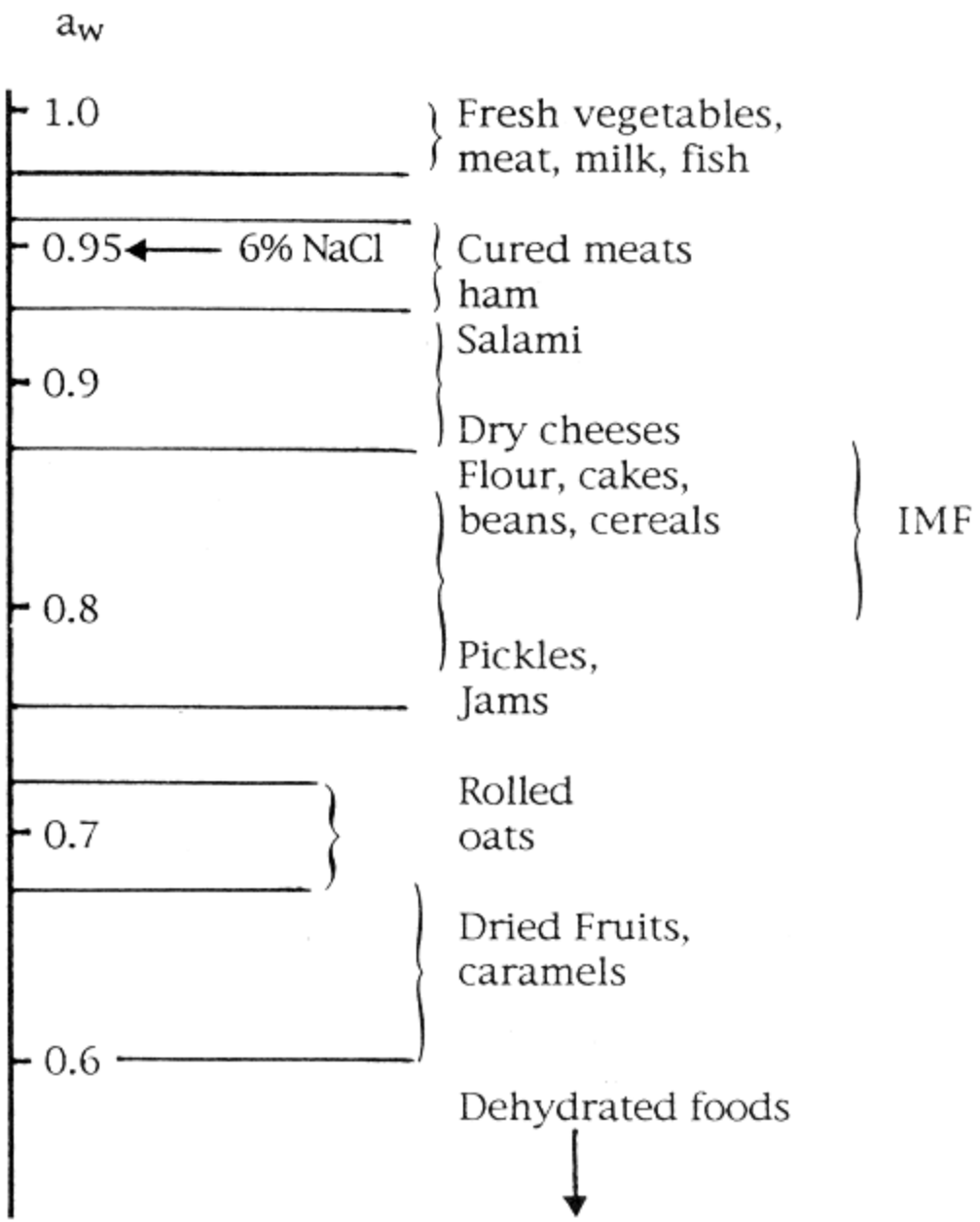
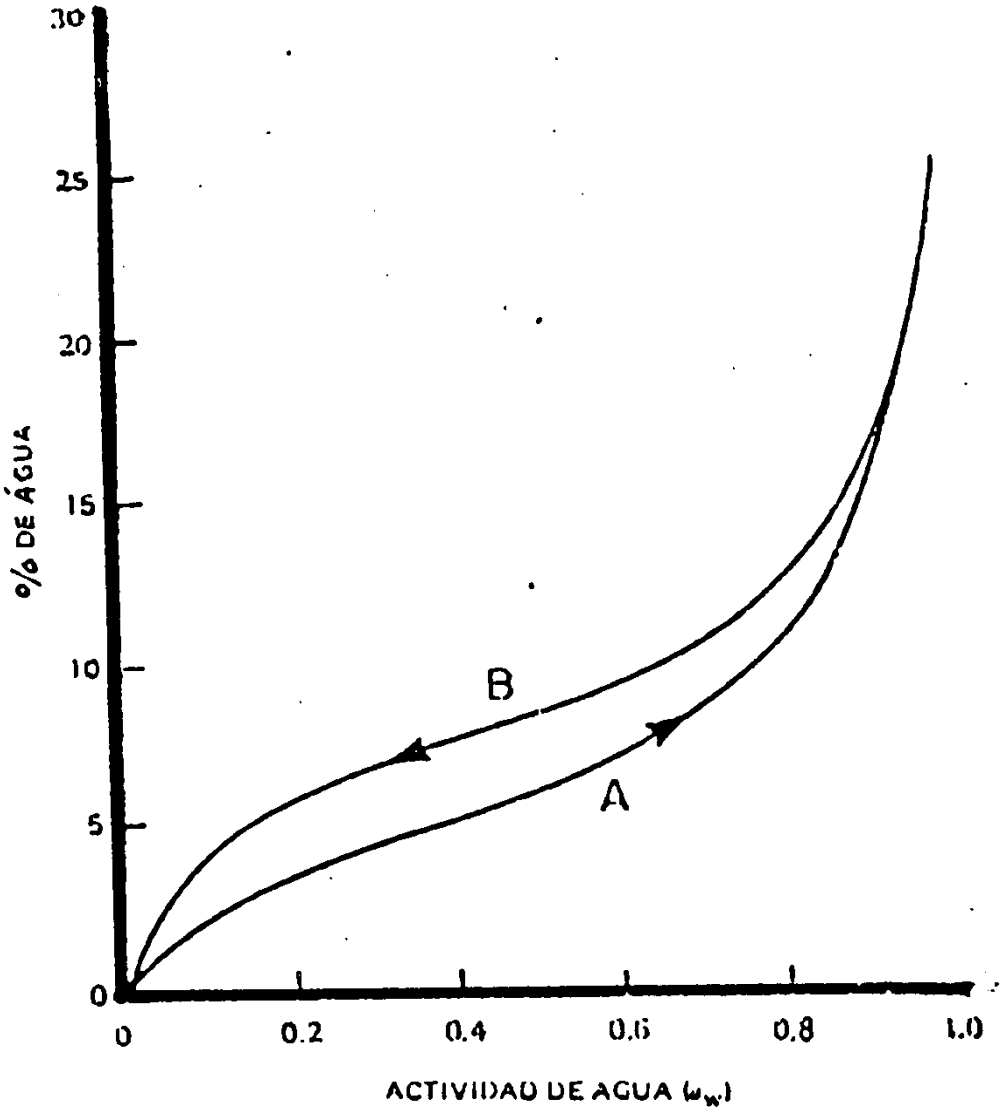


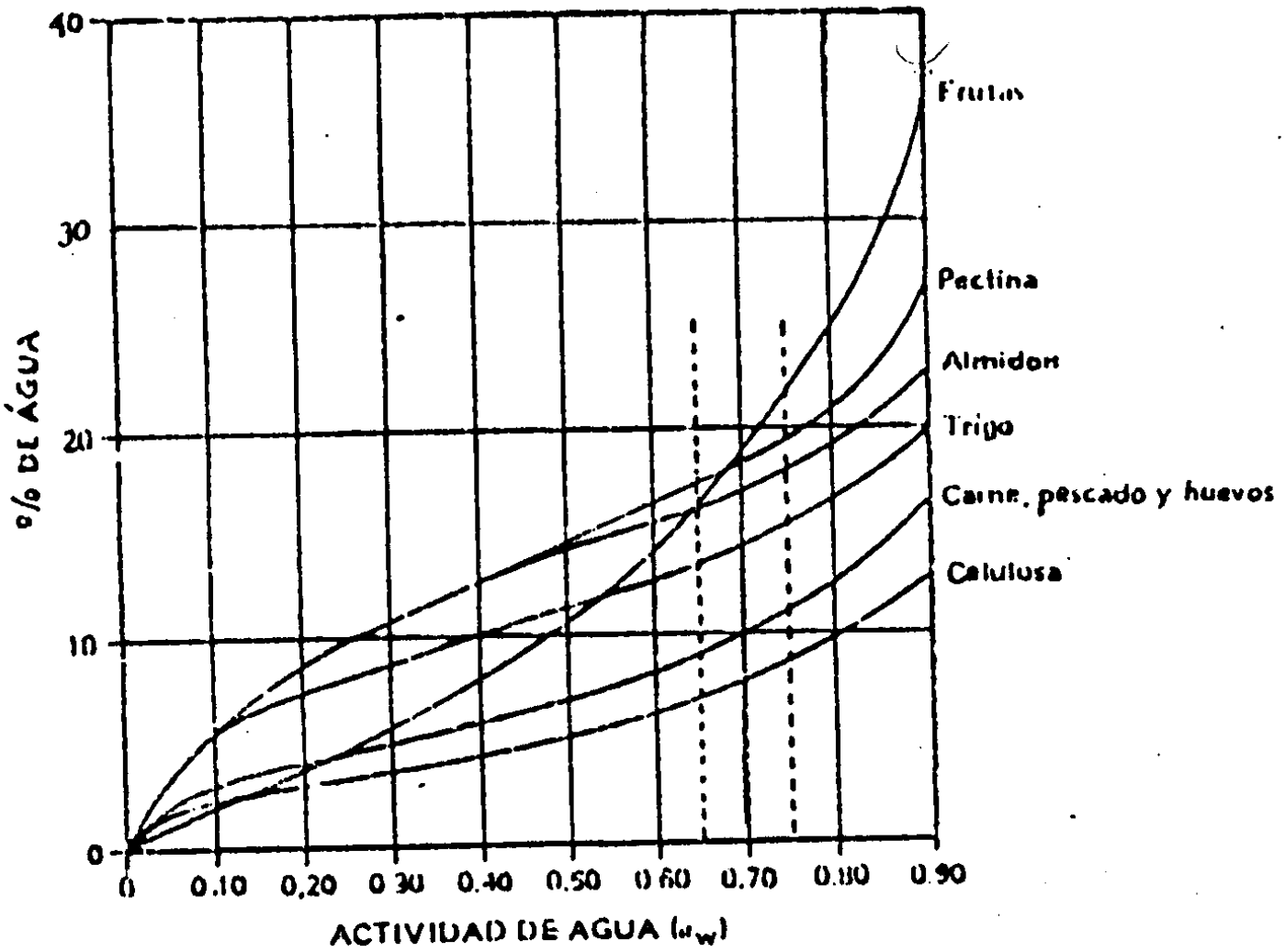
Figure 3.9 *Range of* a_w *values associated with a number of food commodities*



ISOTERMAS DE SORÇÃO DE ÁGUA EM QUE SE MOSTRA A HISTERESIS.

A - ADSORÇÃO

B - DESORÇÃO



ISOTERMAS DE SORÇÃO DE VAPOR DE ÁGUA DE ALGUNS ALIMENTOS A 20°C

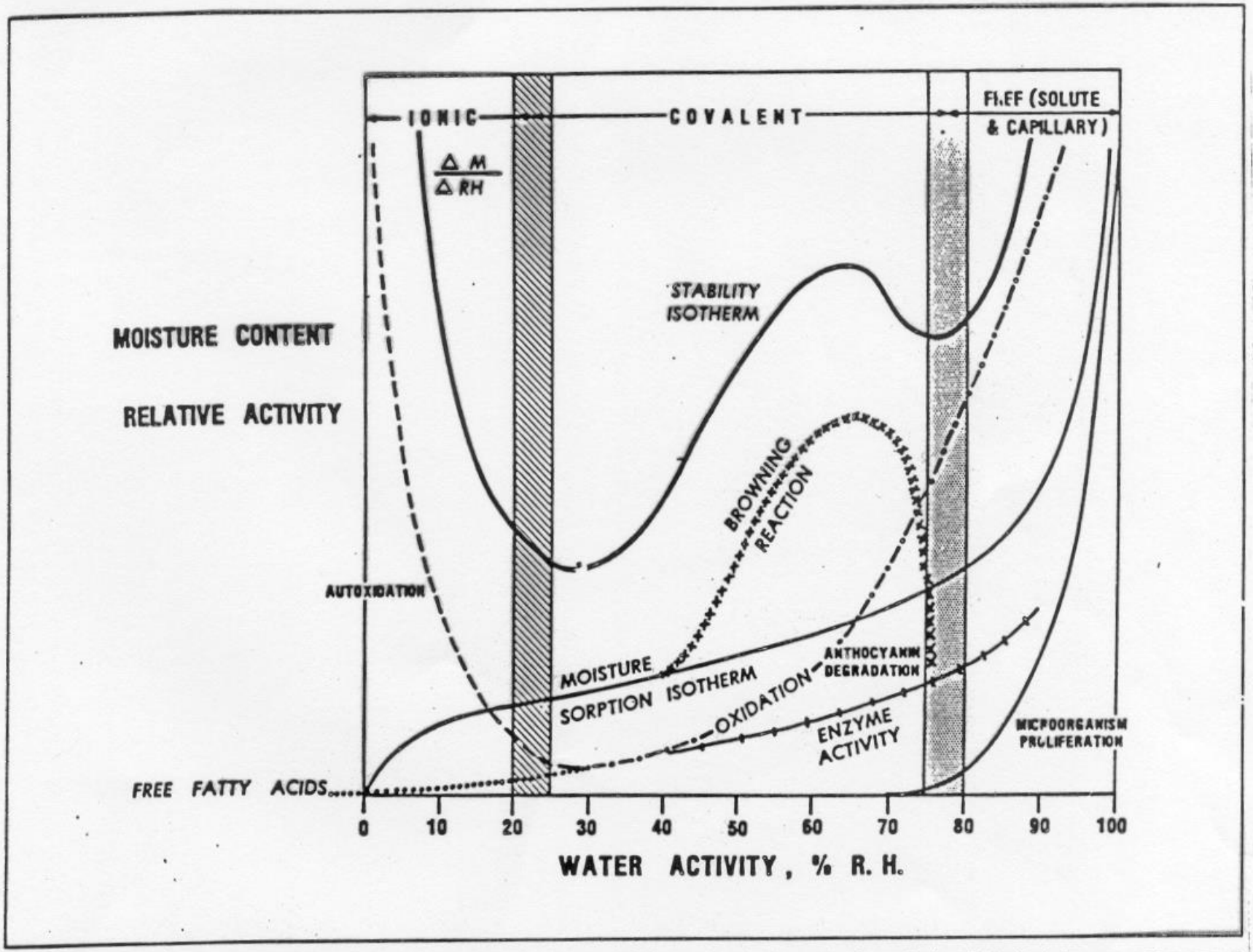


Fig. 3—**DIAGRAMATIC REPRESENTATION** *of the influence of water activity on chemical, enzymatic, and microbiological changes and on overall stability and moisture sorption properties of food products*

Potencial redox

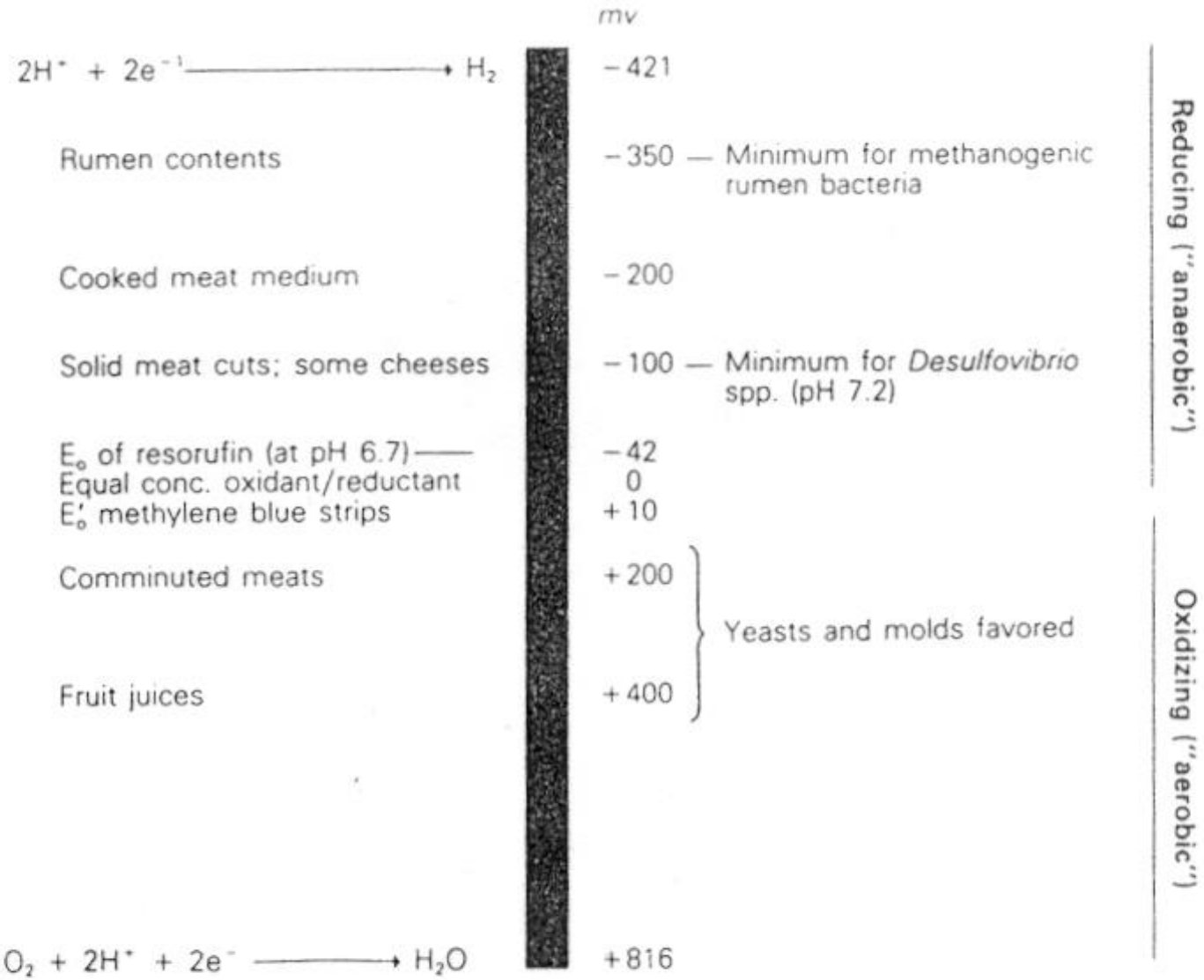


Figure 3.3. Schematic representation of oxidation–reduction potentials relative to the growth of certain microorganisms.

Table 3.5 *Redox Potentials of some food materials*

	E(mV)	*pH*
Raw meat (post-rigor)	−200	5.7
Raw minced meat	+225	5.9
Cooked sausages and canned meats	−20 to −150	*ca.* 6.5
Wheat (whole grain)	−320 to −360	6.0
Barley (ground grain)	+225	7.0
Potato tuber	*ca.* −150	*ca.* 6.0
Spinach	+74	6.2
Pear	+436	4.2
Grape	+409	3.9
Lemon	+383	2.2

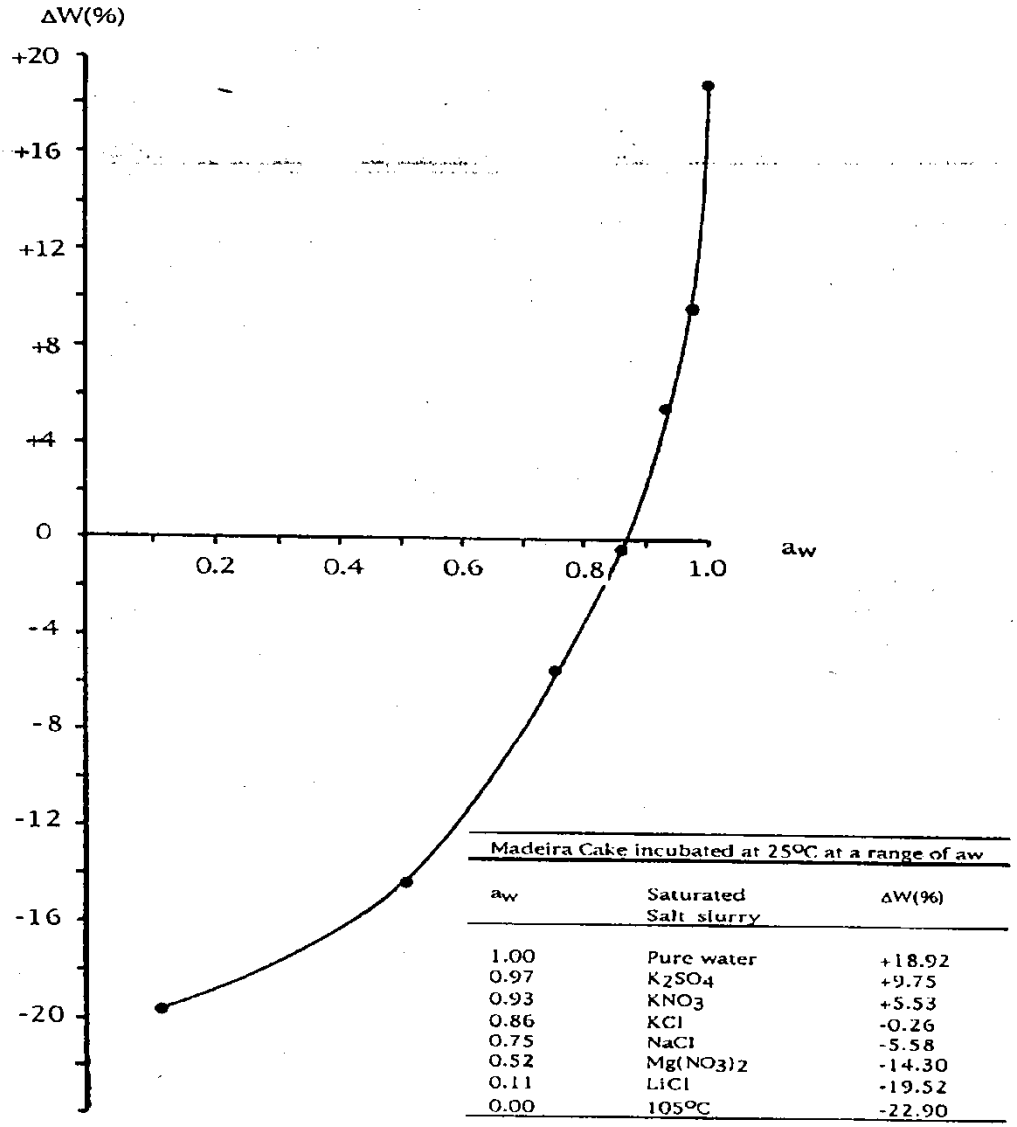
Table 3.3 *Factors influencing the measured E_h of foods*

Redox couples present
Ratio of oxidant to reductant
pH
Poising capacity
Availability of oxygen (physical state, packing)
Microbial activity

Factores ambientais

- Humidade relativa
- Temperatura
- Atmosfera gasosa

Efeito da humidade relativa

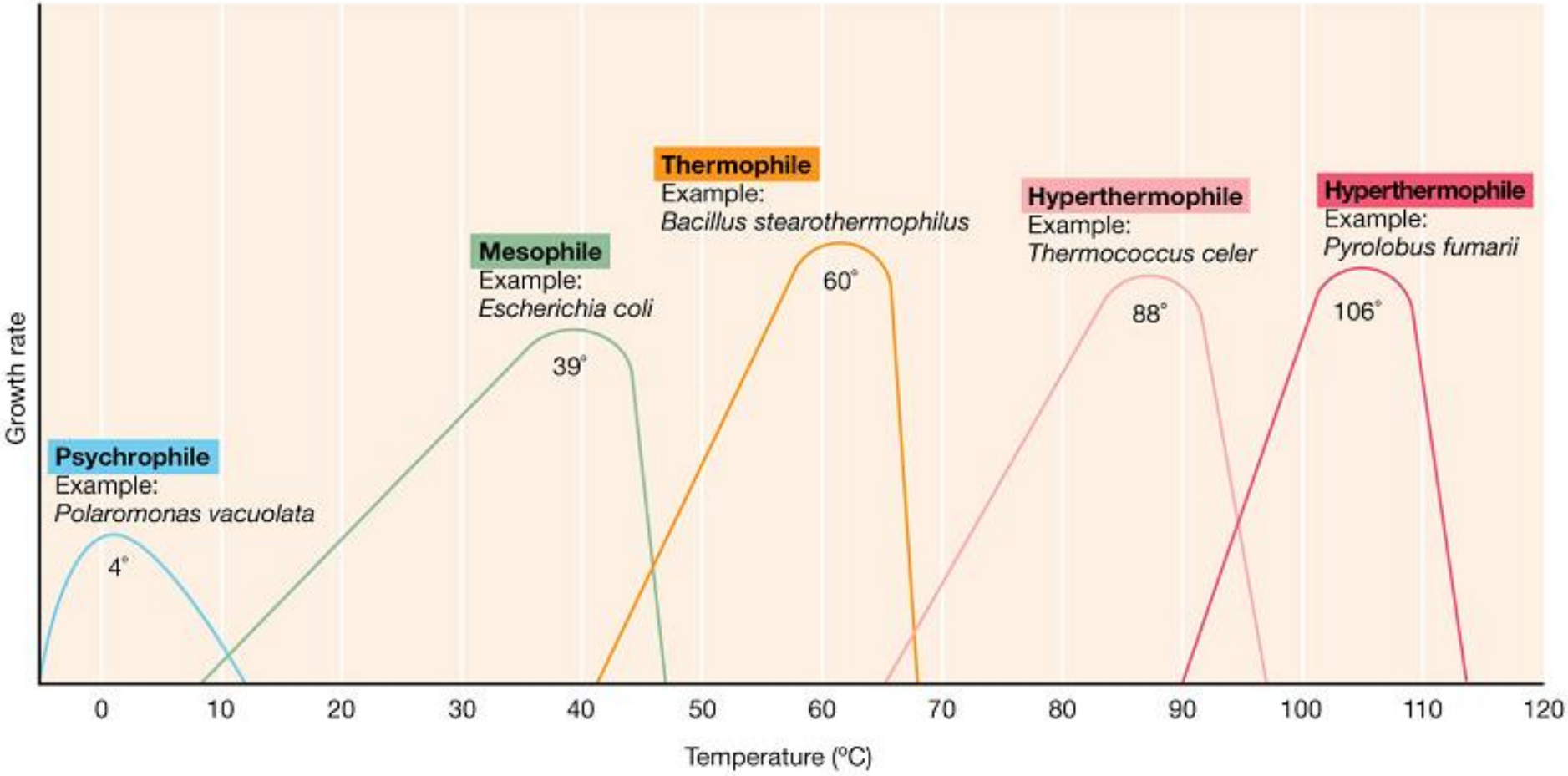


Madeira Cake incubated at 25°C at a range of aw

a_w	Saturated Salt slurry	ΔW(%)
1.00	Pure water	+18.92
0.97	K_2SO_4	+9.75
0.93	KNO_3	+5.53
0.86	KCl	-0.26
0.75	NaCl	-5.58
0.52	$Mg(NO_3)_2$	-14.30
0.11	LiCl	-19.52
0.00	105°C	-22.90

Figure 3.12 *Weight changes of samples of madeira cake at different ERH values*

Temperatura



Implicações da T no crescimento microbiano

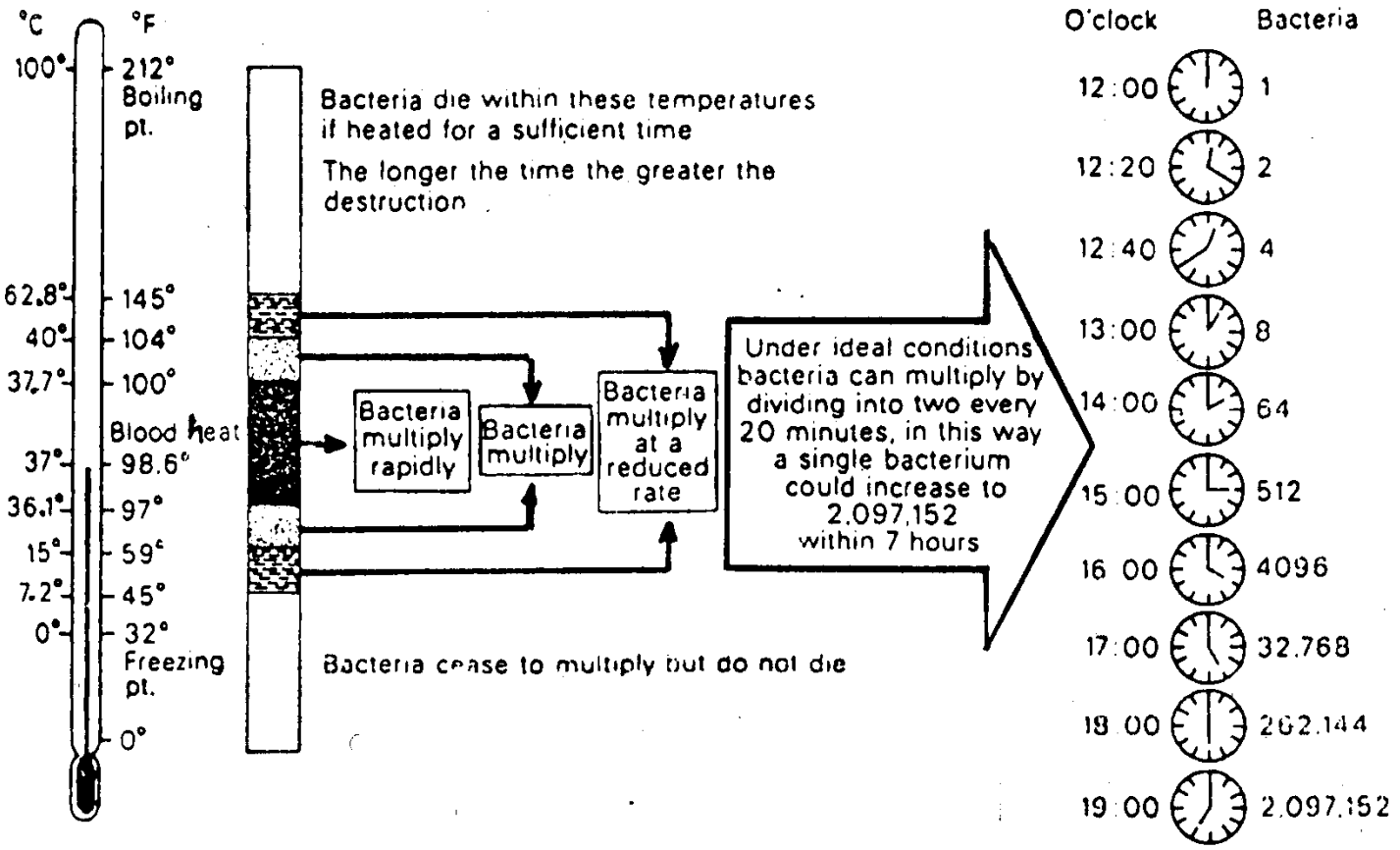


Figure 3.4. Effect of temperature and time on the growth of bacteria. Safe and dangerous temperatures for foodstuffs. *From Hobbs* (53), *reproduced with permission of the publisher.*

Atmosfera gasosa

Table 4.13 *MAP gas mixtures used with foods*

Product	*% CO_2*	*% O_2*	*% N_2*
Fresh meat	30	30	40
	15–40	60–85	–
Cured meat	20–50	0	50–80
Sliced cooked roast beef	75	10	15
Eggs	20	0	80
	0	0	100
Poultry	25–30	0	70–75
	60–75	5–10	> 20
	100	0	0
	20–40	60–80	0
Pork	20	80	0
Processed meats	0	0	100
Fish (white)	40	30	30
Fish (oily)	40	0	60
	60	0	40
Cheese (hard)	0–70		30–100
Cheese	0	0	100
Cheese;grated/sliced	30	0	70
Sandwiches	20–100	0–10	0–100
Pasta	0	0	100
	70–80	0	20–30
Bakery	0	0	100
	100	0	0

From *J. Food Protection*, 1991, **54**, 58–70, with permission

Factores de processamento

- Lavagem
- Fatiagem/Moenda
- Processos tecnológicos de conservação
- Embalagem
- …

Efeito barreira

- Interacção de factores condicionantes da dinâmica das populações

- Estratégias modernas para garantir a estabilidade microbiana dos alimentos (análise de casos)

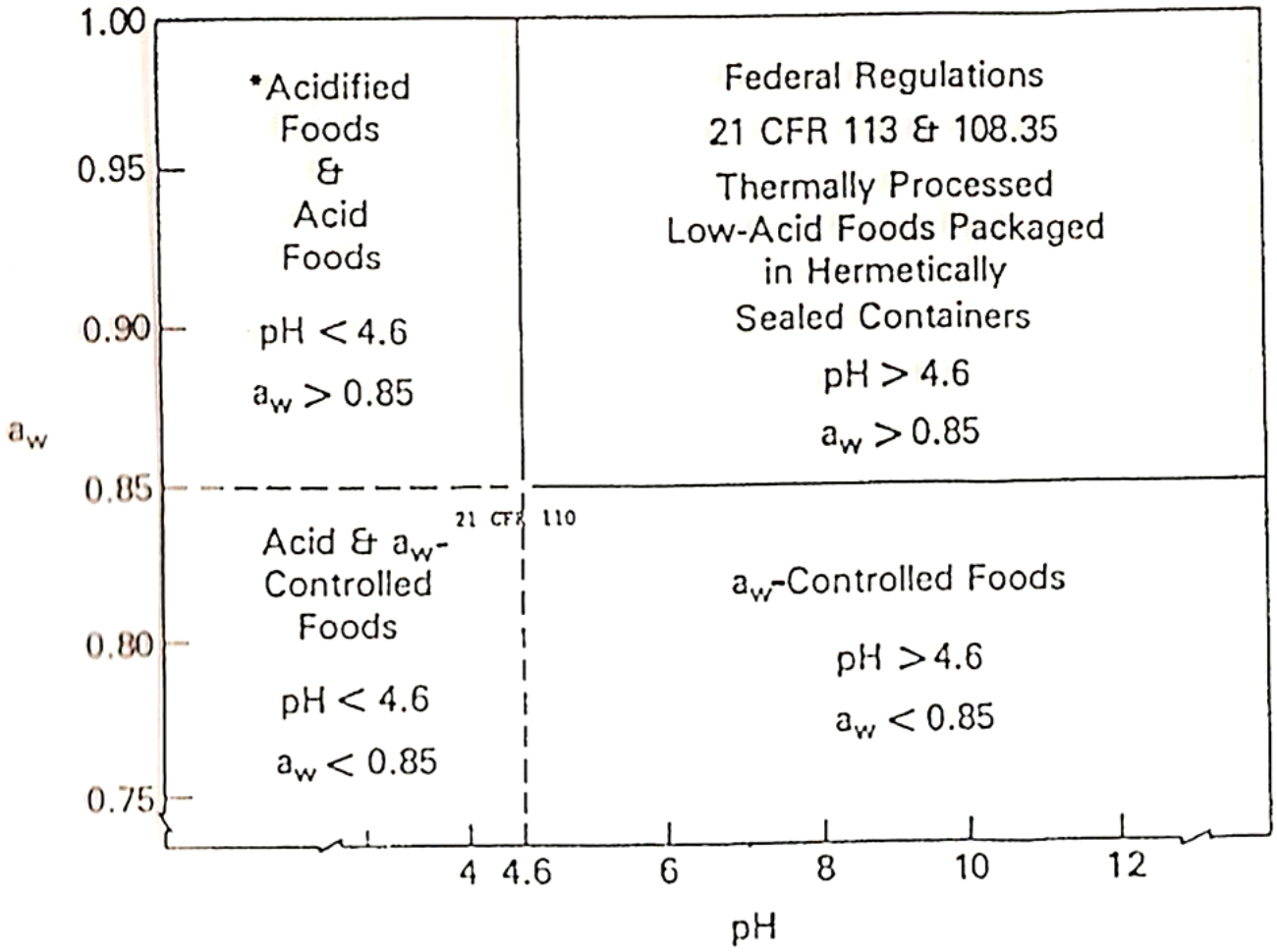


FIGURE 2 FDA Good Manufacturing Practice Regulations governing processing requirements and classification of foods. *Acidified foods—21 CFR 114 & 108.25. (From Ref. 31.)

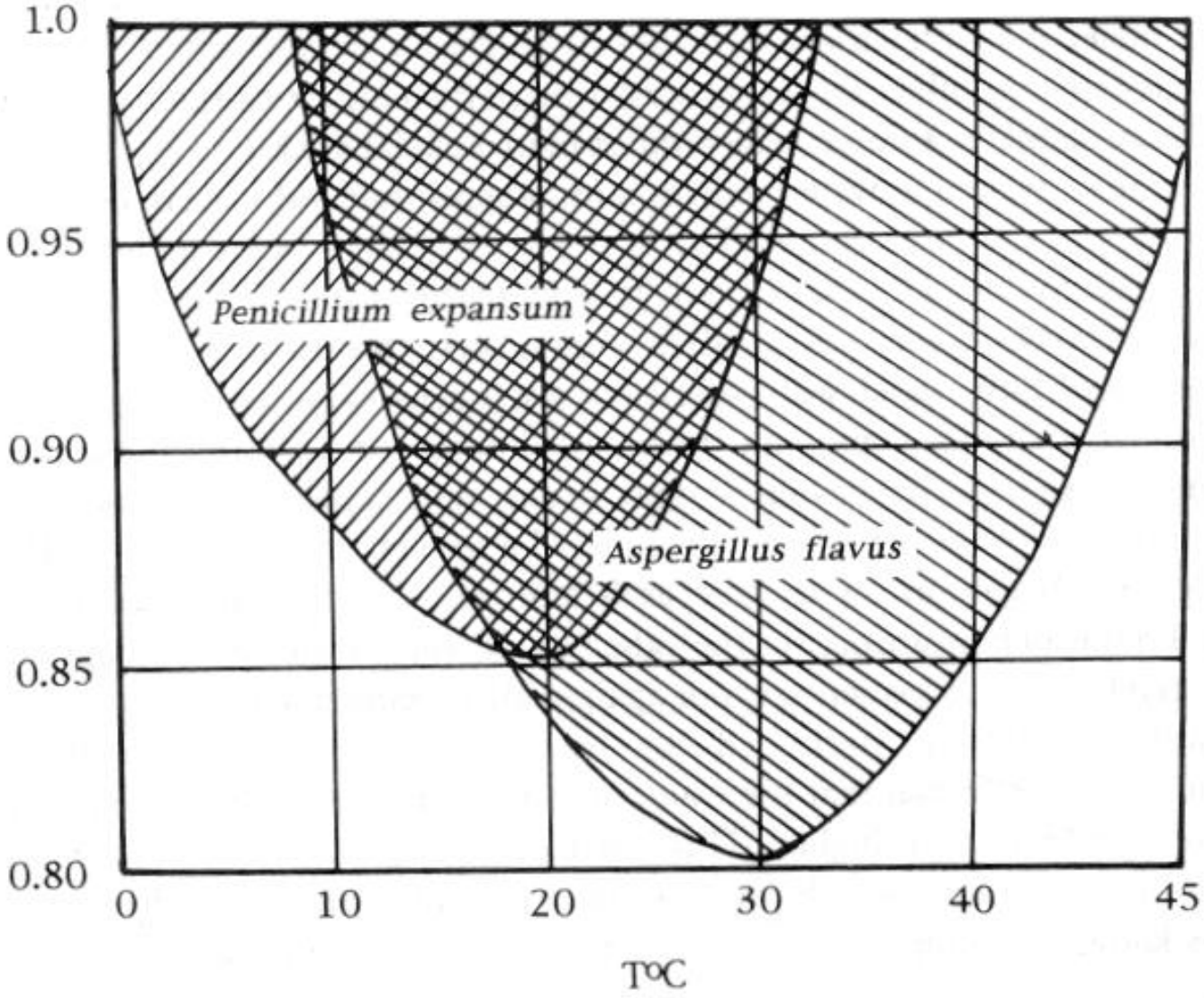


Figure 3.8 *Temperature water activity combinations allowing the growth of* Aspergillus flavus *and* Penicillium expansum

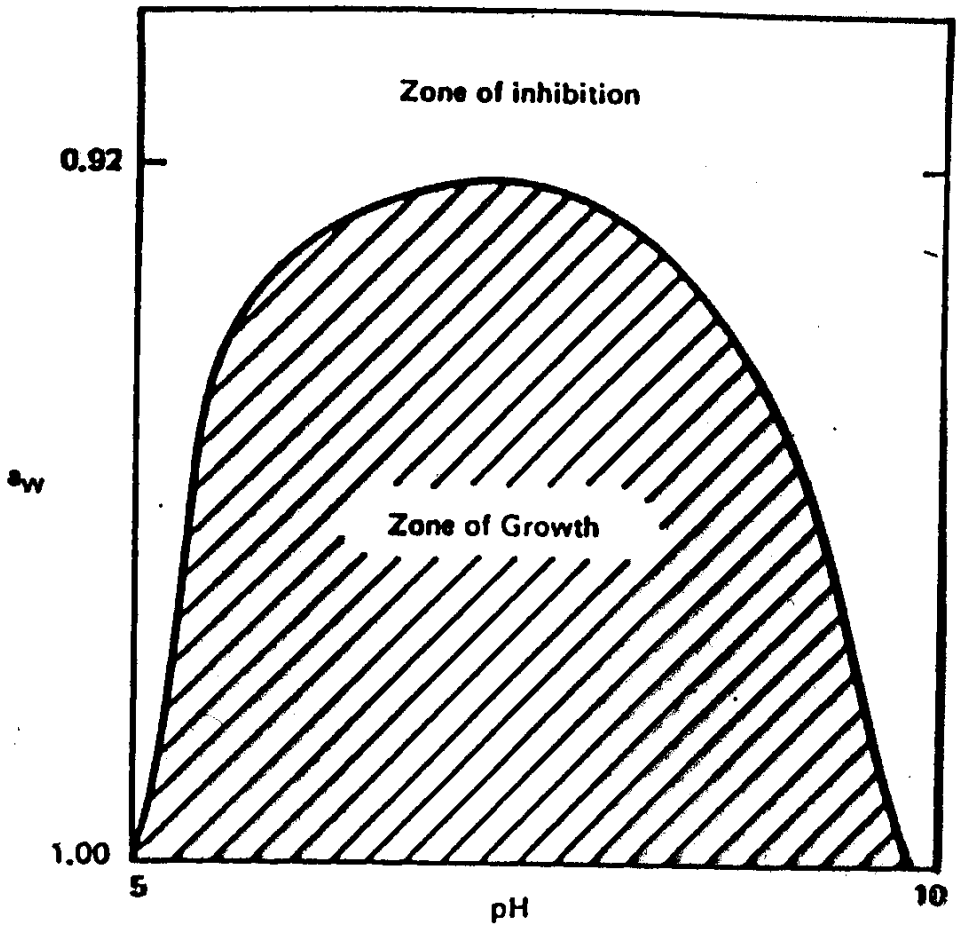


FIGURE 1 Effects of pH and water activity interaction on bacterial growth. (From Ref. 65.)

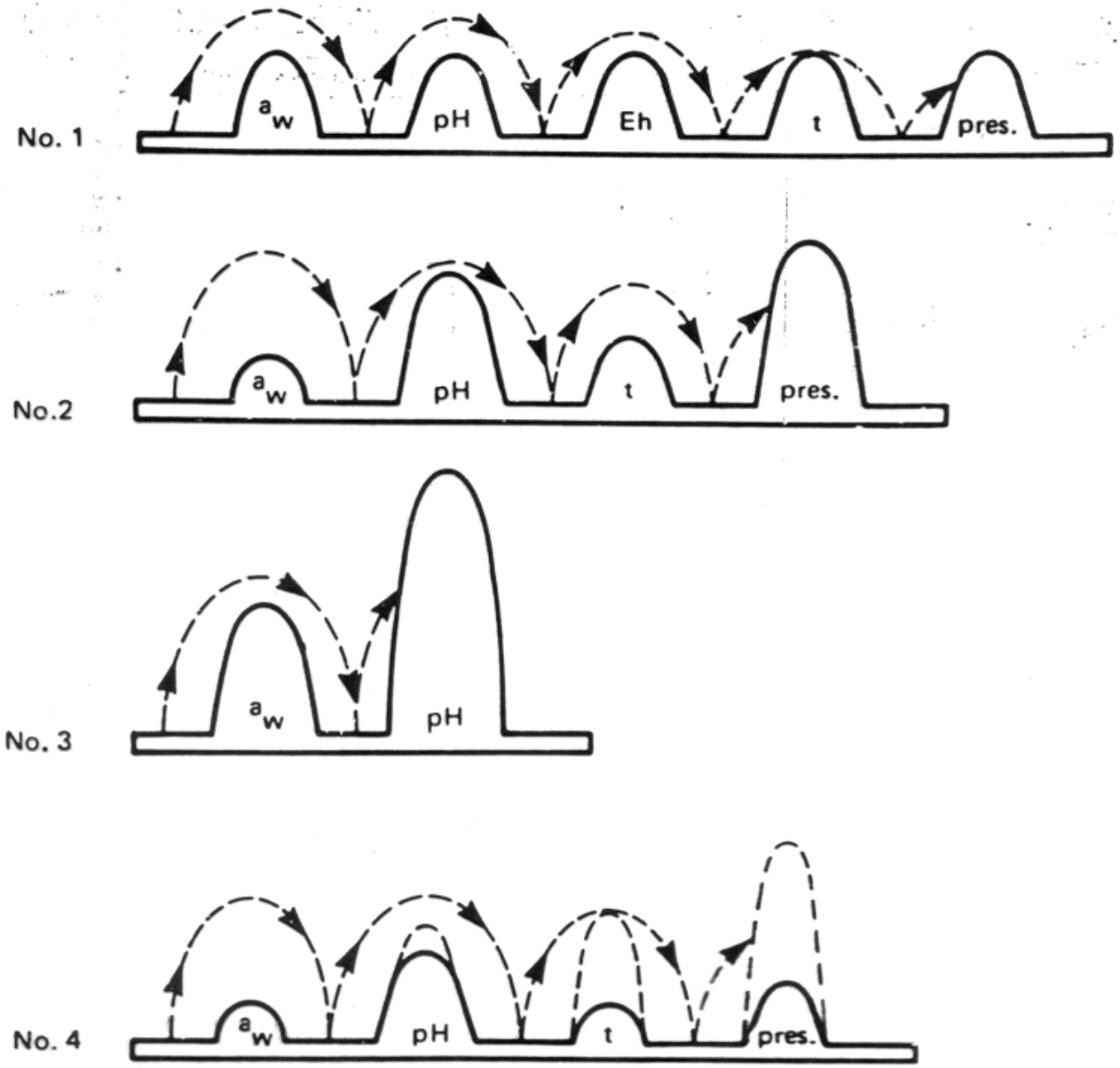


Fig. 4.1 Hurdle effect, illustrated using four food products as example. (*From Leistner 1978.*)

Table 1. HURDLES USED TO INCREASE SHELF-LIFE

Hurdle	Application	Shelf-life	Quality losses
initial selection; packaging; wax coatings	pretreatment; fresh refrigerated	a few weeks	market disorder; increased rot
refrigeration	fresh, MA[1] stored products; single strength juices	depending on perishability; > 1 year	chilling injuries; weight losses
freezing	fresh, blanched products; concentrates	> 1 year	nutritional, texture losses; discoloration, aesthetic change, enzymatic browning
CA[2]	fresh/refrigerated products	extended	softening; discoloration; retarded spoilage
pasteurization	for all products	stable, according to F-value	nutritional losses; sensory losses
canning (sterilization)	fruit juices/canned fruit	depending on initial contamination	nutritional losses; sensory losses
drying	fruits, juices	months, depending on moisture level	discoloration; flavour changes; mould growth
preservatives	juices, soft drinks, concentrates, pulp, nectars	rather short	consumer aversion, resistance

1 = Modified Atmosphere
2 = Controlled Atmosphere

Tabela 2.4 Métodos de conservação de alimentos*

Operação	Efeito esperado
Limpeza, lavagem	Redução da carga microbiana
Estocagem a frio (abaixo de 8°C)	Previne o crescimento da maioria das bactérias patogênicas; retarda o crescimento de microrganismos deteriorantes
Congelamento (abaixo de –10°C)	Previne o crescimento de todos os microrganismos
Pasteurização (60-80°C)	Mata a maioria das bactérias não-esporuladas, mofos e leveduras
Branqueamento (95-110°C)	Mata bactérias vegetativas superficiais, mofos e leveduras
Enlatamento (acima de 100°C)	Esteriliza comercialmente alimentos, mata todas as bactérias patogênicas
Secagem	Cessa o crescimento de todos os microrganismos quando a a_w** < 0,60
Salga	Cessa o crescimento da maioria dos microrganismos com uma concentração de sal de 10%
Aumento da concentração (açúcares)	Inativa o crescimento quando $a_w < 0,70$
Acidificação	Inativa o crescimento da maioria das bactérias (os efeitos dependem do tipo de ácidos)

*Fonte: ICMSF, 1988.
**a_w denota atividade de água.

Forsythe (2000)

Tabela 2.12 Conservantes antimicrobianos para alimentos*

Conservantes (faixa de concentração típica, mg/kg)	Exemplos de uso
Ácidos orgânicos fracos e ésteres conservantes	
Propionato (1-5.000)	Pães, produtos de panificação e queijos
Sorbato (1-2.000)	Queijos frescos e processados, produtos lácteos, produtos de panificação, xaropes, geléias, gelatinas, refrigerantes, margarinas, bolos, temperos
Benzoato (1-3.000)	Picles, refrigerantes, temperos, peixes semi-conservados, geléias, margarinas
Ésteres benzoatos (parabenzenos, 10)	Produtos de peixe marinados
Ácidos orgânicos acidulantes	
Ácidos láctico, cítrico, málico, acético (sem limitações)	Molhos com baixo pH, maioneses, temperos, cremes para salada, bebidas, sucos de fruta e concentrados, produtos à base de carne e vegetais
Ácidos inorgânicos conservantes	
Sulfito (1-450)	Pedaços de frutas, frutas desidratadas, vinho, embutidos de carne
Nitrato e nitrito (50)	Produtos de carne curada
Ácidos minerais acidulantes	
Ácido fosfórico, ácido hidroclórico	Bebidas
Antibióticos	
Nisina	Queijo, alimentos enlatados
Natamicina (primaricina)	Sucos de frutas industrializados
Fumaça	Carne e peixe

*Adaptada de Gould e reimpressa com permissão de Elsevier Science, *International Journal of Food Microbiology*, 1996, 33, 51-64.

Conservantes ácidos

Proportion of total acid undissociated at different pH values (expressed as percentages)					
	pH				
	3	**4**	**5**	**6**	**7**
Acetic acid	98.5	84.5	34.9	5.1	0.54
Benzoic acid	93.5	59.3	12.8	1.44	0.144
Citric acid	53.0	18.9	0.41	0.006	<0.001
Lactic acid	86.6	39.2	6.05	0.64	0.064
Methyl, ethyl, propyl parabens	>99.99	99.99	99.96	99.66	96.72
Propionic acid	98.5	87.6	41.7	6.67	0.71
Sorbic acid	97.4	82.0	30.0	4.1	0.48
Source: Table 7.3 in ICMSF 1980, p 133.					

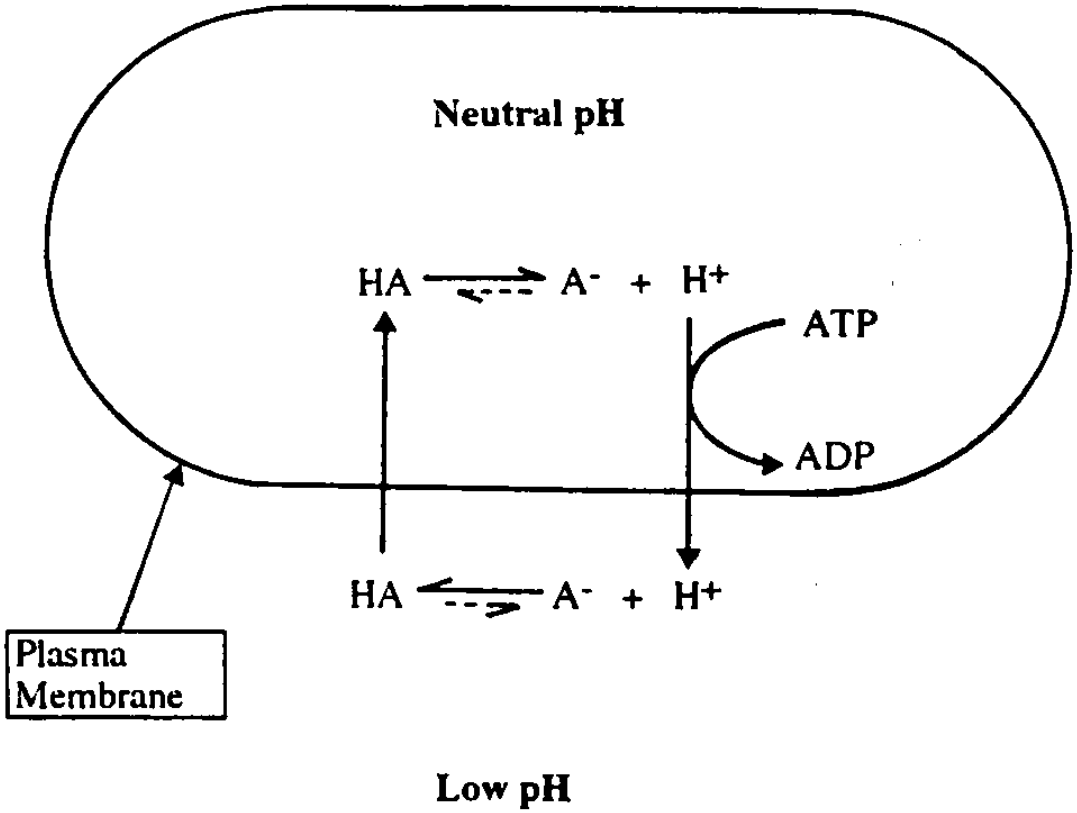


Figure 3.2 *Microbial inhibition by weak organic acids*

Conservação dos principais grupos de alimentos

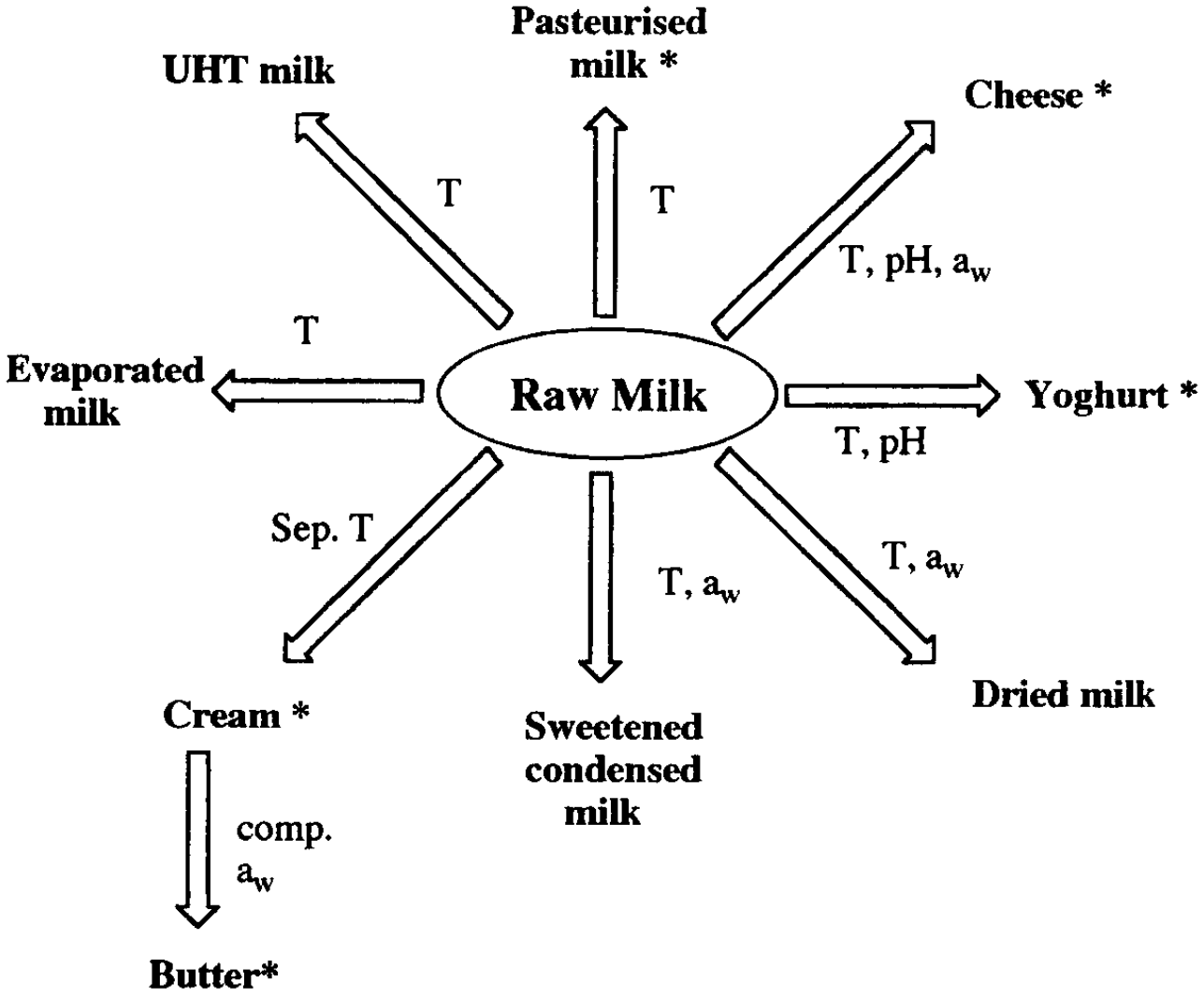


Figure 5.3 *Milk and milk products. T indicates elevated temperature; pH, reduced pH;* a_w*, reduced* a_w*; sep., separation, comp., compartmentalization; and *, stored at chill temperatures*

Composição do Músculo (%)

Adams e Moss (2000)

Peixe

- Lípidos 0,5-25
- Proteína 15-20
- Hidratos de C < 1
  - Consumidos na morte
- pH 6,2-6,5
  - Excepto alabote
- TMAO (Oxido de Tri-Metilamina)

Carne

- Lípidos 2,5
- Proteína 19
- Hidratos de C 1,2
  - Ácido láctico 0,9
  - Glicogénio 0,1
- pH 7,0-5,4
  - redução depois da morte
- Outros 2,3

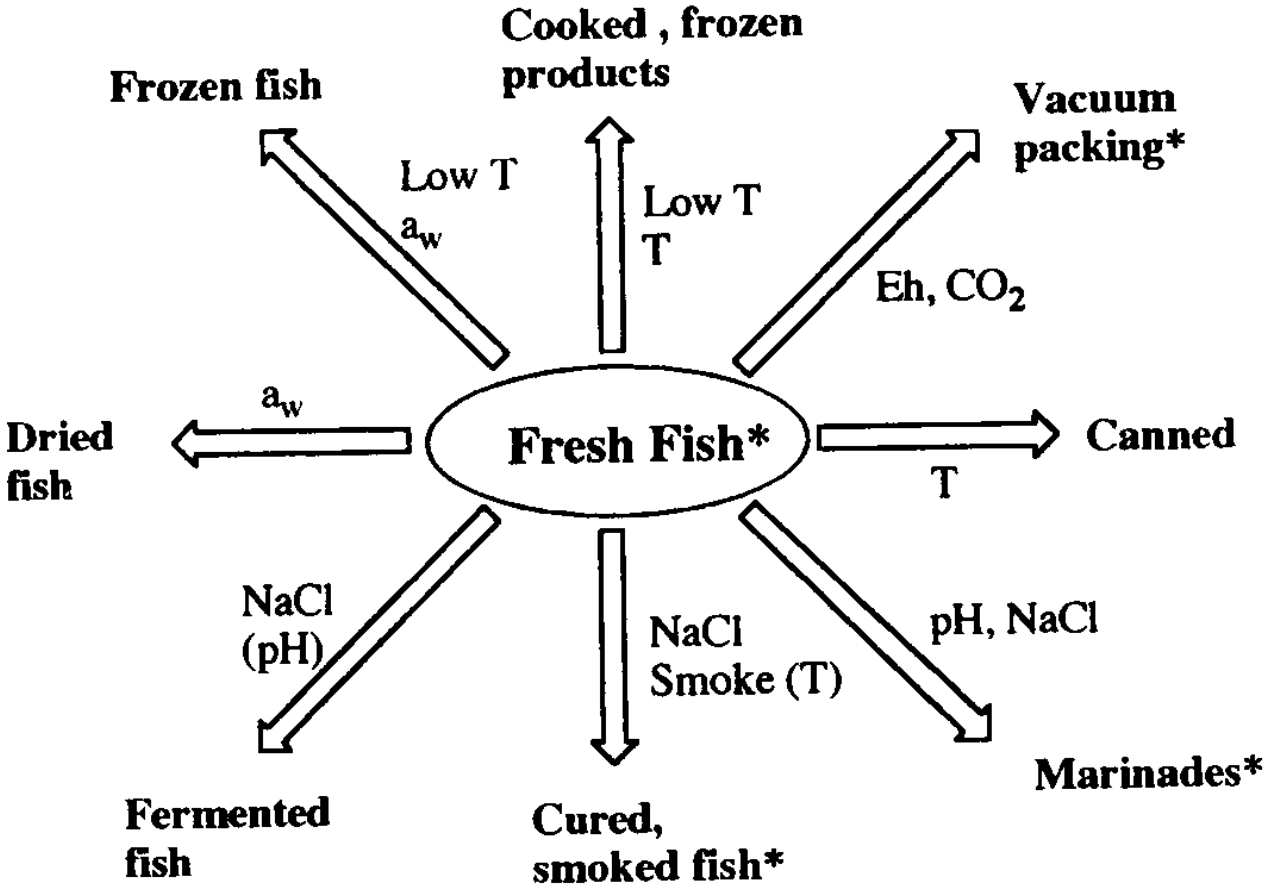


Figure 5.7 *Fish and fish products.* T *indicates elevated temperature;* E_h, *low redox potential; pH, reduced pH;* a_w, *reduced* a_w; *and* * *stored at chill temperatures*

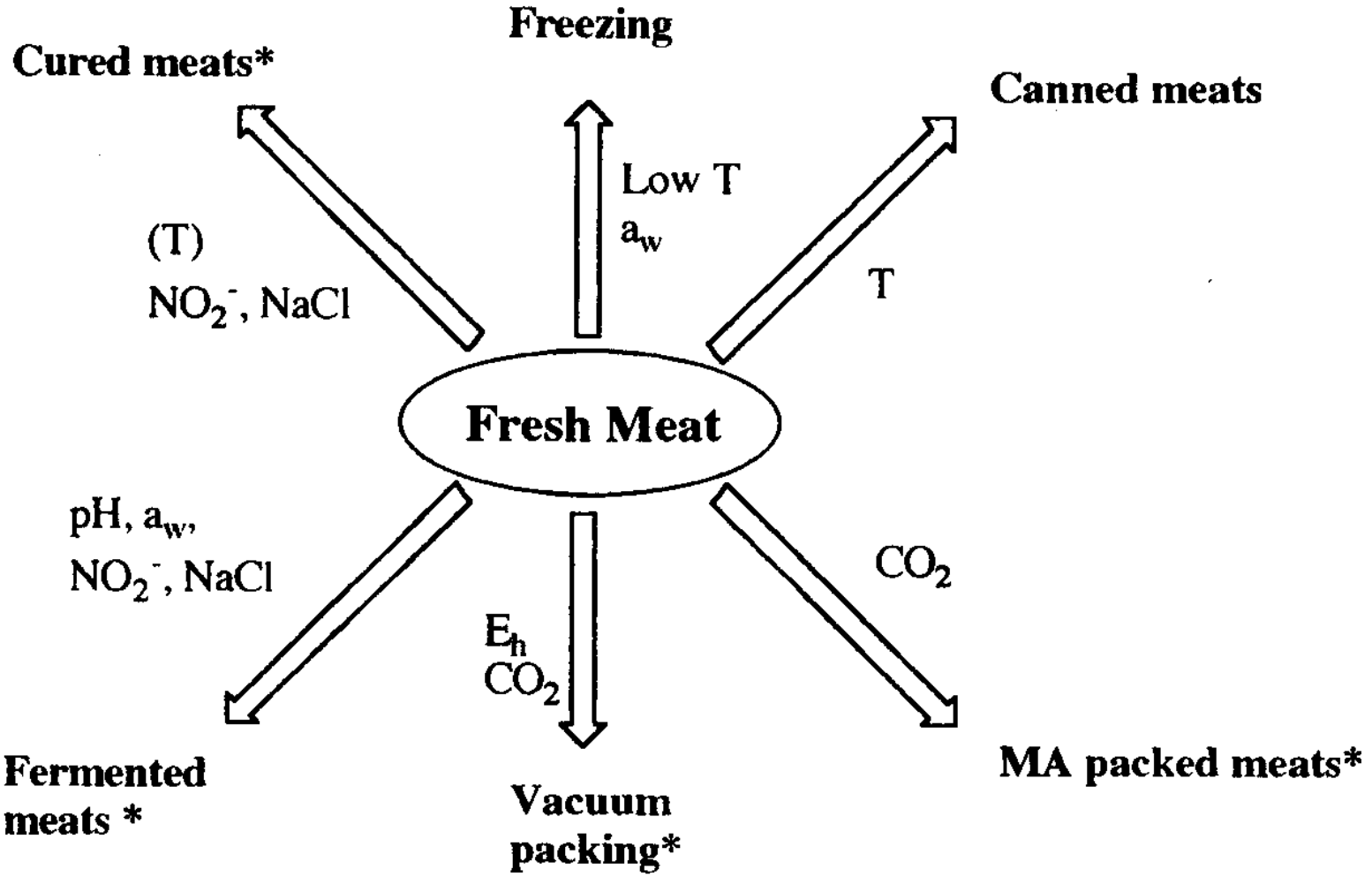
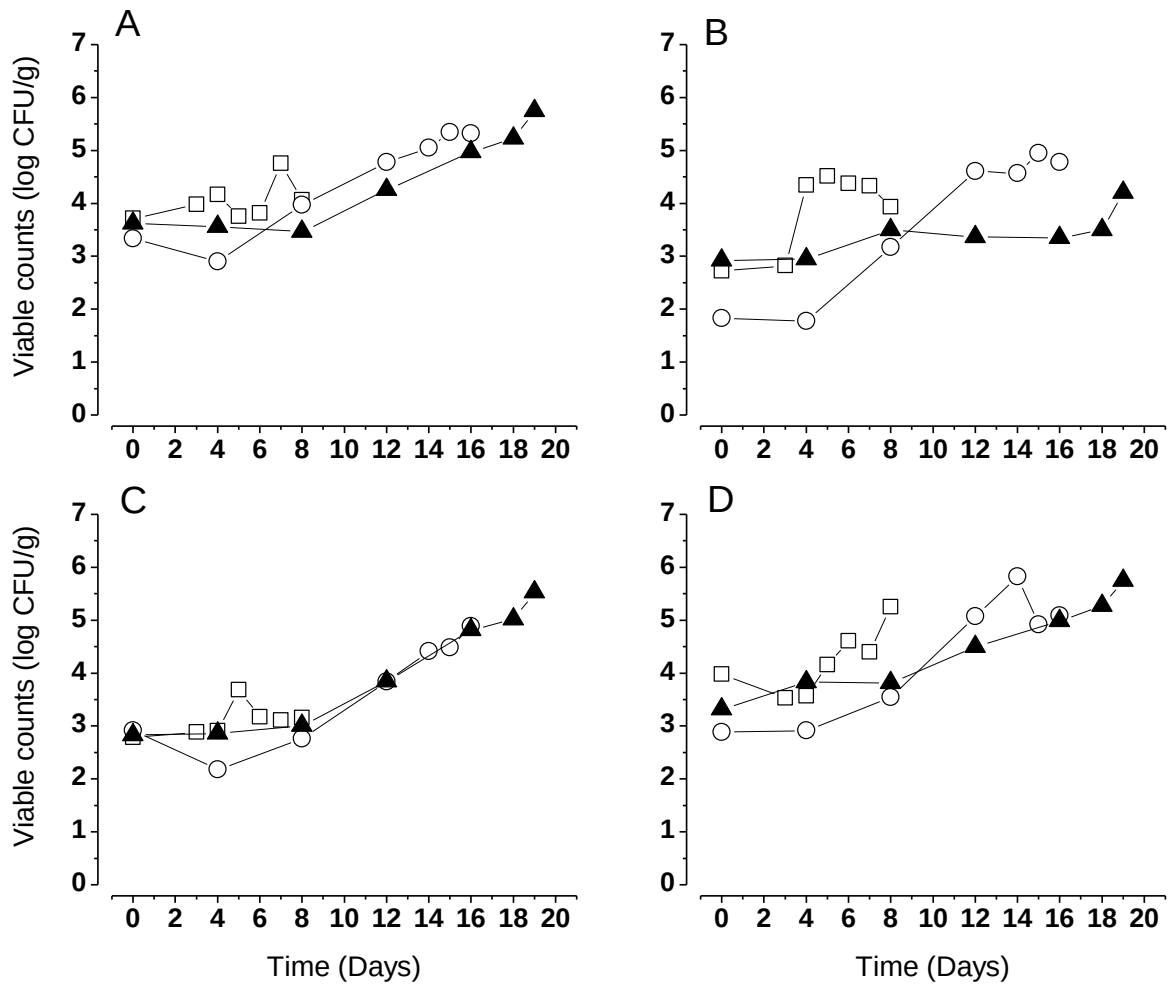


Figure 5.5 *Meat and meat products.* T *indicates elevated temperature;* E_h, *low redox potential; pH, reduced pH;* a_w, *reduced* a_w; *and* * *stored at chill temperatures*

Estudo de caso

Contaminações em carne fresca de coelho embalada em diferentes atmosferas

Evolution of microbial indicators of refrigerated rabbit carcasses packaged in: bulk (□), under air (○) and under modified atmosphere (▲).
A: mesophilic aerobic counts; B: *Pseudomonas*; C: Lactic acid bacteria; D: aerobic psycrothropic counts.

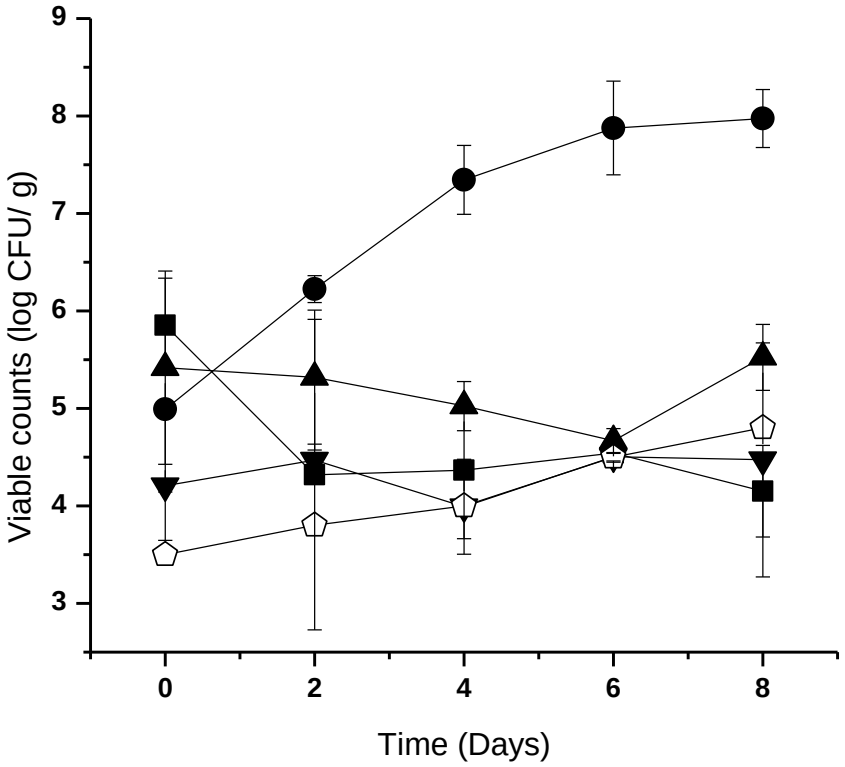


Growth parameters of aerobic mesophilic, aerobic psychrotrophic, *Pseudomonas,* lactic acid bacteria and yeasts and moulds populations according to packaging type in rabbit carcasses

Microbial group	Bulk packaging			Air packaging			Modified atmosphere packaging		
	Lag phase (days)	Growth rate (day^{-1})	Increment (days)	Lag phase (days)	Growth rate (day^{-1})	Increment (days)	Lag phase (days)	Growth rate (day^{-1})	Increment (days)
Aerobic mesophiles	**4**	**0.19±0.21**	**5.3**	**4**	**0.20±0.01**	**5.0**	**8**	**0.19±0.01**	**5.3**
Aerobic psicrophiles	**4**	**0.36±0.09**	**2.8**	**4**	**0.21±0.05**	**4.8**	**8**	**0.16±0.02**	**6.3**
Pseudomonas	**3 - 4**	**0.00**	**–**	**4**	**0.26±0.03**	**3.9**	**–**	**0.00**	**–**
Lactic acid bacteria	**–**	**0.00**	**–**	**4**	**0.23±0.01**	**4.3**	**8**	**0.22±0.01**	**4.5**

Challenge test

Evolution of the viability of *Listeria innocua* (●), *Staphylococcus aureus* (▲), *Salmonella* spp. (▼), *Escherichia coli* (■) and aerobic mesophilic bacteria (⌂) on rabbit carcasses incubated at 8 ºC.



Tabelas

Categorias de alimentos

TABLE 6.10. CLASSIFICATION OF THE MAJOR FOODS IN ORDER OF INCREASING COLONIZATION RESISTANCE, I.E. MICROBIOLOGICAL KEEPING QUALITY IN AIR

Class	'Processing' including heat treatment, compositional modification and packing	Stability characteristic: Storage temp. (°C)	Stability characteristic: Time of spoilage-free storage[a]	Examples	Predominant microbial community structure when storage period has expired
1-1	**None of functional nature; natural pH ⩾ 4.5**	**⩽7**	**10–40 h**	**Fresh meat, milk, fish, poultry, eggs** Vegetables	**Psychrotrophic, non-fermentative** Gram-negative rods
1-2	Pasteurization, followed by hermetic packing	⩽7	3 days to 2 weeks	Dairy products Refrigerated pasteurized (REPFED, or 'sous-vide') meals	Sporing rods, psychrotrophic bacteria resulting from post-process recontamination
1-3	Curing with NaCl, containing $NaNO_2$, leading to a slight reduction in a_w, but particularly, bacteristatic levels of nitrite, followed by pasteurization	⩽7	1–2 weeks	Meat products	Micrococci, *Brochothrix*, streptococci, lactobacilli
1-4	Reduction of water activity to *c.* 0.95, pH reduction and addition of preservatives, in combination with hermetic packing	⩽7	A few weeks	'Gaffelbitter'[c] and similar semi-preserved fish products	Streptococci, lactobacilli, moulds and yeasts
2-1	Reduction of water activity to *c.* 0.85, pH/a_w/lactic acid — combinations of equivalent microbistatic effect, pasteurization	Ambient	Many weeks	Condensed milk Mayonnaise, margarine, Smoked sausage	Yeasts, moulds
2-2	Reduction of water activity to *c.* 0.80, sometimes in combination with pH reduction by fermentation, or the addition of vinegar	Ambient	'Unlimited', until chemical reactions interfere	Shelf-stable products such as salami, stockfish and sauces	Moulds
2-3	Reduction of water activity to <0.60	Ambient	'Unlimited'	Dehydrated foods	Bacilli, *Enterococcus* spp., mould spores
2-4	Appertization[b]	⩽40	'Unlimited'	Canned cured-meat products and fruits	An occasional spore, i.e. cfu count $\ll 10^2\,g^{-1}$
2-5	Sterilization	Any	'Unlimited'	Canned milk, soups, meat, vegetables and fish	None

Source: Mossel *et al.* (1984).

[a] The refrigerated storage life of the foods of classes 1-1 and 1-2 can be substantially increased by modified-atmosphere packaging (Drosinos and Board, 1994).

[b] Heat treatment of hermetically sealed foods leading to microbiologically safe, although not necessarily sterile, stable products (see section 8.3.11).

[c] Tasty titbits made of fish.

Microrganismos de alteração de alimentos

TABLA XI

Asociaciones alterantes de las clases más importantes de alimentos

Características del alimento					Asociación							
					Bacilos Gram -							
Clase	pH	Valor de a_w	Tratamiento tecnológico con efecto microbicida	Ejemplos	No ferm*.	Ferm.	Cocos catalasa +	Cocos catalasa -	*Lactobacillaceae*	*Bacillaceae*	Mohos	Levaduras
1	>4.5	>0.95	Ninguno	Carnes frescas, pescado, mariscos, carne de aves, huevos y ovoproductos	+++	+	+	±	0	0	+	0
2	>4.5	>0.95	Ninguno	Vegetales	+++	±	0	±	+	+	+	0
3	>4.5	<0.90	Ninguno	Cereales, legumbres	+	+	+	0	+	+	+++	+
4 A	<4.5	>0.95	Ninguno	Frutas	0	±	0	0	++	0	++	+
B	<4.5	>0.95	Ninguno	Jugos	++†	±	0	++	++	0	±	++
C	<4.5	>0.95	Ninguno	Mayonesa, salsas para ensaladas, ensaladas de carne, pescado, etc.	0	0	0	+	+++	0	++	++
D	<4.5	≈ 0.95	Fermentación	Prod. fermentados: vegetales, carnes, pescado, productos lácteos	0	0	0	+++	+++	0	++	++
5	>4.5	>0.95	Pasterización	Leche y helados	±	±	±	+	±	++	0	0
6	>4.5	>0.95	Pasterización	Embutidos cocidos, jamones enlatados	0	0	±	+	+	++	0	0
7	>4.5	≈0.95	Al horno	Pan, tartas	0	0	0	0	0	+	++	±
8 A	>4.5	<0.90	Variable	Vegetales desecados, legumbres, cereales y cacao	0	0	0	0	0	0	+++	0
B	>4.5	<0.90	Ninguno	Mazapán, rellenos de chocolate	0	0	0	0	±	0	+	++
C	<4.5	<0.90	Desecado	Frutas desecadas	0	0	0	0	±	0	++	++
9	≈ 4.5	≈0.96	Ninguno	Mantequilla y margarina saladas	0	0	±	±	0	0	+	+
10 A	>4.5	>0.95	Appertización††	Carnes, pescado, vegetales y leche envasados en recipientes herméticos	0	0	±	0	0	++	0	0
B	<4.5	>0.95	Pasterización	Frutas y zumos envasados en recipientes herméticos	0	0	0	0	0	±	++	+

Frecuencia: +++, casi de forma exclusiva; ++, dominante; +, significativo; ± de poca importancia u ocasional; 0, virtualmente de ninguna importancia.

* Grupo *Pseudomonas/Acinetobacter/Alcaligenes*, a menos que se indique otra cosa.
† Grupo *Acetobacter/Gluconobacter*.
†† Tratamiento térmico en envases herméticos, determinante de productos microbiológicamente estables a temperaturas por debajo de los 40° C.

Comunidades microbianas em alimentos

TABLE 5.1. MICROBIAL COMMUNITY STRUCTURE AT CONSUMER OUTLETS (MICROBIAL 'ASSOCIATION') OF THE MOST IMPORTANT CLASSES OF STAPLE FOODS OF GOOD QUALITY

Attributes of food on which their ecological grouping is based					Association +++, virtually exclusive and at all times; ++, dominant; +, significant; ±, minor or occasional; 0, of almost no importance							
					Gram-negative rods							
Class	pH	a_w	Processing with microbicidal effect	Examples	Non-ferm.[a]	Ferm.	Catalase +cocci	Catalase −cocci	Lacto-bacillaceae	Bacil-laceae	Moulds	Yeasts
7	>4.5	c. 0.95	Baking	Bread, rolls, cakes	0	0	0	0	0	+	++	±
8A	>4.5	<0.90	Variable	Dried vegetables, pulses, cereals and cocoa	0	0	0	0	0	0	+++	0
B	>4.5	<0.90	None	Marzipan, chocolate fillings	0	0	0	0	±	0	+	++
C	<4.5	<0.90	Drying	Dried fruits	0	0	0	0	±	0	++	++
9	c. 4.5	c. 0.96	None	Salted butter and margarine	0	0	±	±	0	0	+	+
10A	>4.5	>0.95	Appert-ization[c]	Meats, fish, vege-tables and milk packed in hermeti-cally sealed containers	0	0	±	0	0	++	0	0
B	<4.5	>0.95	Pasteur-ization	Fruits and juices packed in hermeti-cally sealed containers	0	0	0	0	0	±	++	++

Source: Mossel (1975a).

[a] The *Pseudomonas/Acinetobacter/Alcaligenes* group, unless otherwise indicated.

[b] The *Acetobacter/Gluconobacter* group.

[c] Heat treatment of hermetically packed foods, leading to products, microbiologically safe, and stable at temperatures below c. 40 °C (see section 6.4.2).

Bactérias Gram^{+} c/ significado em alimentos

TABLE 2.3. GROUPING, AT GENUS LEVEL, OF GRAM-POSITIVE BACTERIA OF SIGNIFICANCE FOR FOODS

Morphology	Biochemistry[a]	Type genera
Rods, no spores	Catalase +	*Corynebacterium/Brevibacterium/ Arthrobacter/Microbacterium*[b] *Brochothrix*[c]
Rods, no spores	Catalase θ	*Lactobacillus/Carnobacterium*
Rods, with spores	Catalase +	*Bacillus*[d]
Rods, with spores	Catalase θ	
	Glucose type[e] 5 or 1	*Clostridium*[f]
Coccus	Catalase +	
	glucose type 1 or 2	*Micrococcus, Deinococcus*
	glucose type 3	*Staphylococcus*[g]
Coccus	Catalase θ	
	glucose type 3	*Streptococcus*[h]
	glucose type 4	*Leuconostoc*

Modified after Mossel (1983a).

[a] Reactions for c. 90% of the most frequently isolated strains.

[b] Mesophilic: $D_{65} \geqslant 2$ min (see section 3.3 for definition of *D*-values).

[c] Rods changing to cocci in old cultures; psychrotrophic: D_{50} approx. 2 min.

[d] *B. cereus*: no attack on mannitol, but dissimilation of egg-yolk.

[e] Glucose type: 1, no attack; 2, oxidative dissimilation; 3, fermentative anaerogenic dissimilation; 4, aerogenic fermentative dissimilation; 5, strict anaerobic dissimilation.

[f] *Cl. perfringens*: non-motile, indole-negative.

[g] *Staph. aureus*: coagulase +; mode of attack on mannitol type 3, i.e. fermentative, but anaerogenic in >90% of strains.

[h] Group D: growth with black haloes on kanamycin–aesculin–azide agar at 42 °C; group N: growth on sorbic acid–tomato juice agar of pH 4.5; group A: β-haemolytic on sulpha-methoxazole–trimethoprim–blood agar.

TABLE 2.12. GROUPING AT GENUS LEVEL OF GRAM-NEGATIVE BACTERIA OF SIGNIFICANCE IN FOODS AND WATER

Biochemistry[a]	Type genera
Oxidase θ	
glucose type 1[b]	*Legionella*
glucose type 2[b]	*Acetobacter/Gluconobacter*
glucose type 1 or 2[b]	
motile	*Xanthomonas*
non-motile	*Acinetobacter*
glucose type 3 or 4[b]	
lactose +	
citrate θ	*Escherichia*[c]
citrate +	
MR +	*Citrobacter/Kluyvera*[d]
MR θ	
motile	*Enterobacter/Erwinia*[e]
non-motile	*Klebsiella*
lactose θ	
β-gal θ	
motile	
urea θ	*Salmonella*
urea +	*Proteus*
non-motile	*Shigella*
β-gal +	
H_2S +	*Citrobacter*[f]
H_2S θ	
LD θ	*Yersinia*
LD +	
arabinose +	*Hafnia*
arabinose θ	*Serratia*[g]
Oxidase +	
glucose type 1	
motile	*Alcaligenes/Comamonas*[h]
non-motile	*Moraxella/Flavobacter*
glucose type 2	*Pseudomonas*[i]
glucose type 3	*Beneckea/Vibrio*[h]
glucose type 4	*Aeromonas*[i]

Bactérias Gram$^-$ não fermentativas em alimentos

TABLE 2.13. OVERVIEW OF NON-FERMENTATIVE GRAM-NEGATIVE RODS

Genus or group	Mot	Ox	Gluc ox	Pigment Exo	Pigment Endo	L 10% ox	C	Ni	Arg (anaer)	Starch	Additional traits
Pseudomonas											
Fluorescent (Shewan I; see Table 2.16)	+	pol	+	+	+	θ	±	±	±	+	θ	
Non-fluorescent (Shewan II–IV; see Table 2.16)	+	pol	±	V	θ	θ	θ	±	±	∓	∓	
Xanthomonas	+	pol	∓	+^{s}	θ	+	θ	+	θ	θ	±	Yellow pigment, pen. resistant[a]
Acinetobacter calcoaceticus ('anitratum')	θ		θ	+	θ	θ	+	V	θ	θ	θ	
Other types	θ		∓	±	θ	θ	θ	±	+	θ	θ	
Moraxella	θ		+	θ	θ	θ	θ	θ	±	θ	θ	pen.[a] sens
Flavobacterium	∓	per	±	±	θ	+	+^{s}	V	∓	∓	∓	Yellow, orange or brown pigment
Alcaligenes	+	per	±	θ	θ	θ	θ	±	∓	θ	θ	
Psychrobacter	θ		+	+	θ	θ	...	...	+	...	θ	H_2S θ, non pigmented

[a] pen. = penicillin; ^{s} = slow.
See Table 2.6 for key to other abbreviations.

TABLE 2.23a. THE MOST IMPORTANT GENERA OF DEUTEROMYCETES AND THEIR TELEOMORPHS

Organism			Mycotoxins produced[b] (see Tables 4.18 and 4.19)
Imperfect form	Perfect form[a]	Foods affected	
Alternaria	*Pleospora*	Butter; beef, bacon, poultry; fruits	+
Arthrinium	*Apiospora*	Frozen foods	–
Aspergillus	*Eurotium, Neosartorya* and *Emericella*	See data on the perfect forms in Table 2.23b	+ +
Aureobasidium pullulans		Frozen foods; also grows on paint surfaces in food factories (many yeast-like characters)	–
Botrytis	*Sclerotinia*	'Grey mould' diseases of lettuce, tomato; strawberry and raspberry; soft rots on many fruits and vegetables	+
Cladosporium		Fruit; stored grain; chilled meat	+ +
Epicoccum		Variety of foods	–
Fusarium	*Gibberella*	See data on the perfect form in Table 2.23b	+ +
Geotrichum		Fruits, vegetables; 'film mould' on pickle brine; poultry, dairy products, dry salted fish; contaminant of processing machinery in the fruit and vegetable industry	–
Helminthosporium		Vegetables and grain	+
Humicola		Chilled and frozen foods	–
Myrothecium		Cereals	+
Paecilomyces	*Byssochlamys*	See data on the perfect form in Table 2.23b	+
Penicillium	*Talaromyces* and *Eupenicillium*	See data on the perfect form in Table 2.23b	+ +
Phialophora		Frozen fruit and vegetables	–
Pithomyces		Grass	+
Scopulariopsis		Eggs, cheese, meat products; fruits and vegetables	–
Stachybotrys		Seeds	+ +
Trichoderma		Citrus fruits, cabbage; cereals, peanuts	+
Trichothecium		Fruits, vegetables, cereals	–
Verticillium		Mushrooms	–
Wallemia sebi		Low moisture products	–

[a] For easy reference to perfect forms, see Table 2.23b.

[b] + + = many species mycotoxinogenic; + = toxinogenic species occur amongst many not known to biosynthesize mycotoxins; – = no mycotoxin formation.

TABLE 2.25. GENERA OF SACCHAROMYCETOIDEAE OF IMPORTANCE IN FOODS AND THEIR MAIN PROPERTIES

Genus	Ascus/Ascospores	Pseudomycelium	Biochemical traits[a]	Foods affected
Citeromyces	Thick-walled ascus with one or two warty ascospores	–	F; NO_3 +	Fruits
Debaryomyces	One to two oval, warty spores per ascus		F –; NO_3 –	Fruits, meat, fish, sausage, cheese *D. hansenii*: brines, heavily salted food
Dekkera (perfect form of *Brettanomyces*)	One to four, hat-shaped spores per ascus	+	F; prod. of acetic acid	Beer, wine, soft drinks
Hansenula	One to four hat- or saturn-shaped spores per ascus	+	F ±; NO_3 +	Fermented foods and drinks
Kluyveromyces	One to numerous bean-shaped or spherical spores	±	F; NO_3 –	*Kluyv. marxianus* and *Kluyv. lactis* ferment lactose, and may spoil dairy products
Lodderomyces	One or two large obtuse spores per ascus	+	F (slow); NO_3 –	Soft drinks
Pichia	One to four spherical, hat- or saturn-shaped spores per ascus	+	F ±; NO_3 –	Soft drinks, wine, beer
Saccharomyces (diploid)	One to four spherical or ellipsoidal spores per ascus	±	F; NO_3 –	*Sacch. cerevisiae*: soft drinks and fruit juices
Saccharomycopsis	One to four spherical, hat- or saturn-shaped spores per ascus	+ (and true mycelium)	F ±; NO_3 –; amylase +	A cause of 'chalky' bread
Yarrowia	Variable in size and shape	+	F –; NO_3 –	*Yarrowia lipolytica*: lipolysis in foods rich in lipids
Zygosaccharomyces (haploid)	One to four spherical or ellipsoidal spores per ascus	±	F; NO_3 –	Syrups: high-sugar foods: vinegar-preserved foods

Source: Kreger-van Rij (1984); Beuchat (1987b).
[a]F– = non-fermentative; F = fermentative; NO_3+ = nitrate assimilated; NO_3– = nitrate not assimilated.

Table 5.1 Substrates used for growth and production of metabolites by major meat spoilage bacteria

Bacterium	Substrates used for growth		Major end products of metabolism	
	Aerobic	Anaerobic	Aerobic	Anaerobic
Pseudomonas	Glucose[1] Amino acids[2] Lactic acid[3]		Slime, suphides, esters, acids, amines	
Acinetobacter/ Psychrobacter	Amino acids[1] Lactic acid[2]		Esters, nitriles, oximes, sulphides	
Shewanella putrefaciens	Glucose[1] Amino acids[2] Lactic acid[3]	Glucose[1] Amino acids[2]	Volatile sulphides	H_2S
Brochothrix thermosphacta	Glucose[1] Ribose[2]	Glucose[1]	Acetic acid, acetoin, isovaleric acid, isobutyric acid	Lactic acid, volatile fatty acids, ethanol
Enterobacter	Glucose[1] Glucose-6-phosphate[2] Amino acids[3] Lactic acid	Glucose[1] Glucose-6-phosphate[2] Amino acids[3]	Sulphides, amines	Lactic acid, CO_2, H_2, H_2S, amines
Lactobacillus		Glucose[1] Amino acids[2]		Lactic acid, volatile fatty acids
Leuconostoc		Glucose[1]		Lactic acid, volatile fatty acids, butanoic acid
Carnobacterium		Glucose[1]		Lactic acid, diacetyl, acetate
Clostridium estertheticum		Glucose Amino acids		CO_2, H_2, butanol, ethanol, butanoic acid, esters, volatile sulphur-containing compounds

The superscript number indicates the order of substrate utilisation, where known.
Source: adapted from ICMSF (1996), with additions from Collins *et al.* (1992) and Jones (2004).