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DRY AGING: A FEW GUIDELINES

An essential guide to approaching the maturation of meat with **INOX BIM** Climatic Cabinets

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Definition

Dry aging is a process of *maturation of meat*.

Basically, all kinds of meat can be dry aged. Poultry, rabbit, lamb, and mutton, being animals that usually are slaughtered young, don’t need longer than 3-4 days.

First, bear in mind *all types of meat can be aged*. They simply need different periods of time.

Poultry (chicken, rabbit, turkey, etc.) and sheep (lamb, kid), as a rule, need short times (usually up to 3-4 days) as they are animals who are slaughtered particularly young.

Querry, as well as pork, between 5 and 7 days. The wild boar, the venison, and other animals of a certain size, even up to ten days.

In this research we focus on beef dry aging, which needs a longer time (although the process itself is not overly complex). And it is precisely to beef that most of the scientific literature is dedicated (in addition to most sites or articles in non-specialized magazines): this is the reason why we will mostly talk about *beef*.

The skeletal muscle of a freshly slaughtered animal undergoes a stiffening phase, called *rigor mortis*. In fact, if we cooked and ate the meat shortly after killing, we would find it tough and not very tasty at all.

The dry aging is the time in which biochemical processes take place, softening the meat, as well as intensifying its smell and taste (making it even more digestible).

This period required for dry aging varies not only depending on the type of animal, but also on the muscle, age, the amount of fat and other variables.

There are different kinds of aging. The one we are going to see in detail is the one for which the INOX BIM Climatic Cabinets were conceived and developed: the dry aging.

Before going into the specifics, we deem as necessary to reiterate once again that, since there are several factors on which the aging depends, there cannot be a universally valid manual. The scientific literature itself is, at least on some points, discordant[1].

As the title suggests, here we aim to give you just a few guidelines!

[1] *The dry aged beef paradox: Why dry aging is sometimes not better than wet aging*. N.erjung, F.Witte, V.Heinz. 2020

Processes

The two aspects of the dry aging process that we consider most important are: the *tenderizing of the meat* and the *intensification of flavours*.

On this there seems to be unanimity in the many scientific research: these are definitely improved by the dry aging period[2].

Proteolysis begins a few hours after slaughter. This is a process of degradation of proteins (or peptides) into amino acids by the action of enzymes. By breaking down, the proteins will make the muscle more tender, intensifying flavour and aroma. The enzymes that promote proteolysis are called *calpains*.

Calpains work for a period of about two weeks, and then disintegrate[3]. As it comes to meat tenderization, Calpains are commonly considered to be the most important actresses[4].

There is also a less desired result caused by dry aging: dehydration, and the consequent loss of weight and volume.

• Tenderization

It can be said that there are several factors for the softening of meat, among which we distinguish *pre-mortem* from *post-mortem* ones.

The pre-mortem ones are:

- Race[5], sex[6] and age[7] of the animal.

- Type of rearing[8].

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[2] *Dry-Aging improves meat quality attributes of grass-fed beef loins*. J.Berger; Y.H.B.Kim; J.F.Legako; S.Martini; J.Lee; P.Ebner; S.M.S. Zuelly. 2018

[3] *La scienza della carne*. D.Bressanini. 2019

[4] *Valutazione dell'effetto del sistema calpaina/calpastatina sull'intenerimento della carne di bovino podolico durante la fase di frollatura*. T.Stasi. 2007

[5] *Influence of breed and ageing time on the sensory meat quality and consumer acceptability in intensively reared beef*. Monson, F., Sanudo, C., and Sierra, I. 2005

[6] An experiment with pieces of Aberdeen Angus loin muscles led to different results in terms of texture and flavor among young bulls and heifers of the same age. *The effect of dry aging on instrumental, chemical and microbiological parameters of organic beef loin muscle*. Hulánková, R., Kameník, J., Saláková, A., Závodský, D., & Borilova, G. 2018.

[7] *Studies in Meat Tenderness II. Proteolysis and the Aging of Beef*. Davey C.L.; Gilbert K. 1966.

[8] *Effect of Two Organic Production Strategies and Ageing Time on Textural Characteristics of Beef from the Retinta Breed.* S. Garcia-Torres; A.Lopez-Gajardo; D.Tejerina; E.Prior; M.Cabeza de Vaca; A.Horcada. 2020

- type of muscle[9].

- animal's diet[10], an important factor also in terms of flavour[11].

- quantity and quality of the connective tissue[12].

- quantity and quality of the fat: intramuscular fat reacts with the connective tissue, helping then the tenderization process[13].

- diametre[14] and type[15] of muscular fibres.

And *post-mortem* factors, manageable by controlling the maturation parameters.

Some studies shows that the duration of aging (and its correct implementation) is more important than the pre-mortem factors[16].

It has been stated in some researches that different temperatures, and different percentages of relative humidity, do not provide very different results in long aging, although the bacterial load may be influenced[17].

As for the duration, an experiment conducted on Italian simmental beef revealed that the consistency is better (in terms of tenderness, but also of juiciness) in the sample dry aged for fourteen days rather than seven[18].

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[9] Different muscles have different textures. *The dry aged beef paradox: Why dry aging is sometimes not better than wet aging*. N.Terjung, F.Witte, V.Heinz. 2020

[10] *Effects of different dietary energy and protein levels and sex on growth performance, carcass characteristics and meat quality of F1 Angus × Chinese Xiangxi yellow cattle*. Li, L., Zhu, Y., Wang, X., He, Y., and Cao, B. 2014

[11] Feeding cattles with doses of Vitamin E reduces oxidation and improves the flavor of the maturing meat. *Enhancement of Dry-Aged Beef Quality by Dietary Supplementation of High Levels of Vitamin E*. D.Velazco. 2021.

[12] *Contribution of postmortem muscle biochemistry to the delivery of consistent meat quality with particular focus on the calpain system*. Koohmaraie M.; Geesink G. 2006.

[13] *Components contributing to the improvement of meat taste during storage*. Nishimura T.; Rhue M.R.; Okitani A.; Kato H. 1988

[14] *Valutazione dell'effetto del sistema calpaina/calpastatina sull'intenerimento della carne di bovino podolico durante la fase di frollatura*. T.Stasi. 2007

[15] White muscles have a quicker proteolysis in comparison to red muscles, due to the composition of their fibres. *Proteases and meat quality*. Bickerstaffe, R. 1996

[16] *Assessment of breed type and ageing time effects on beef meat quality using two different texture devices*. M.M.Campo; P.Santolaria; C.Sañudo; J.Lepetit; J.L.Olleta; B.Panea; P.Alberti. 1999

[17] *Influence of aging time, temperature and relative humidity on the sensory quality of dry-aged Belgian Blue beef*. E. Vossen; L. Dewulf; G. Van Royen; I.Van Damme; L.De Zutter; I. Fraeye; S.De Sme. 2022

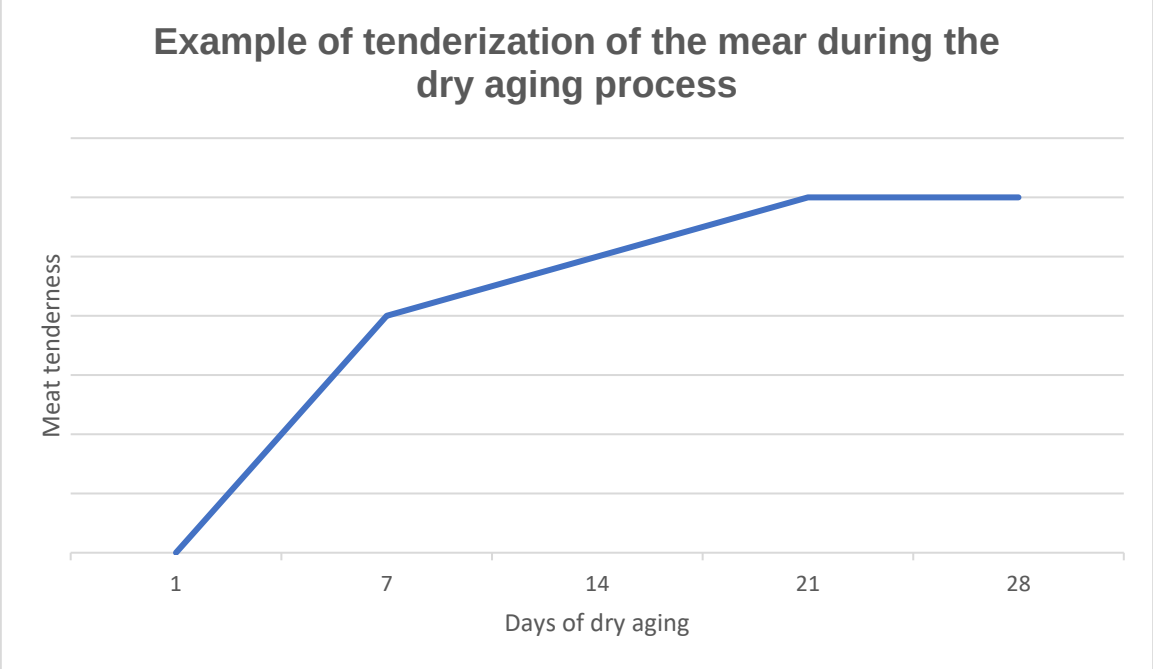
[18] *Effect on ageing time on consumer-perceived quality of Italian Simmental Beef*. E.Plasentier, M.Marangon, M.Morgante, R.Valusso, L.A.Volpelli. 2004

Another study showed that there is no marked difference in consistency in the first 14 days of maturation; tenderization begins to become significant from the twenty-first day, due to the beginning of the processes of denaturation of the muscle[19].

Paradoxically, however, the tendering process shows most of the progress in the first seven days [20] [21].

We will come back to this point when we talk about the duration of the maturation. For the moment, let's keep in mind that:

the processes that lead to muscle tenderization usually occur in the first seven days of maturation. The maximum level of tenderization occurs around the twenty-first day.



[19] *Effects of electrospun chitosan wrapping for dry aging of beef, as studied by microbiological, physicochemical and low-field nuclear magnetic resonance analysis*. Gudjónsdóttir M, Gacutan MD, Mendes AC, Chronakis IS, Jespersen L, Karlsson AH. 2015

[20] *Calpain: Structure, biology and clinical significance*. Panduraman M, Hwang IH. 2013

[21] *Assessment of breed type and ageing time effects on beef meat quality using two different texture devices*. M.M. Campo; P.Santolaria; C.Sañudo; J.Lepetit; J.L.Olleta; B.Panea; P.Alberti. 1999

• Intensification of flavours

The chemical processes that occur during the aging period, in particular the breakdown of proteins and the oxidation of fats[22], bring to the meat its own well-defined flavour, identified as exclusive to beef[23].

By a careful dry aging, one can obtain from the piece of meat a much more intense flavour.

The intensification of the flavour of the meat is due to the evaporation of the water[24], and the consequent drying of the meat (which leads to the concentration of flavour), and to the action of enzymes within the muscles[25], and to the changes taking place in the bacterial flora[26]. Also, the aroma becomes more intense and enjoyable[27].

An important task for the intensification of flavour is also carried out by the *presence of fat*. The latter is not present in large quantities in beef, but is nevertheless very important as it comes to flavour. It is from the fat, in fact, that the typical aromas and flavours of the meat derive[28].

The manifestation of new flavours is due to specific biochemical processes that occur by hydrolysis in a gradual way during the process[29]. The more marked taste that meat subjected to long aging tends towards is *umami*[30]: this name, "tasty" in Japanese, indicate an enjoyable "savoury" flavour, given especially by glutamate[31], and by other kinds of amino acids. Umami is subtle and blends well with the other basic tastes (sweet, sour,

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[22] *Postmortem Aging of Beef with a Special Reference to the Dry Aging*. M.I.Khan; S.Jung; K.Chang Nam; C.Jo. 2016

[23] "Beefy flavour", as mentioned in *Dry aging of Beef; Review*. D.Dashdorj, V.K. Tripathi, S. Cho, Y. Kim, I. Hwang. 2016.

[24] *Dry-aged beef revival: new thoughts on an old process*. Savell, J.W.; Gehring, K. 2018.

[25] Among all the factors, the digestion by enzymes of lactic acid derived from the fermentation of glycogen. *Valutazione dell'effetto del sistema calpaina/calpastatina sull'intenerimento della carne di bovino podolico durante la fase di frollatura*. T.Stasi. 2007

[26] *Changes in microbial composition on the crust by different air flow velocities and their effect on sensory properties of dry-aged beef*. Lee, H. J., Yoon, J. W., Kim, M., Oh, H., Yoon, Y., & Jo, C. 2019.

[27] *A comparative study of beef ageing longissimus muscle using a dry ageing bag, traditional dry ageing or vacuum package ageing*. X. Li; J.Babol; W.L.P.Bredie; B.Nielsen; J.Tomankova; K.Lundstrom. 2014

[28] *Valutazione dell'effetto del sistema calpaina/calpastatina sull'intenerimento della carne di bovino podolico durante la fase di frollatura*. T.Stasi. 2007

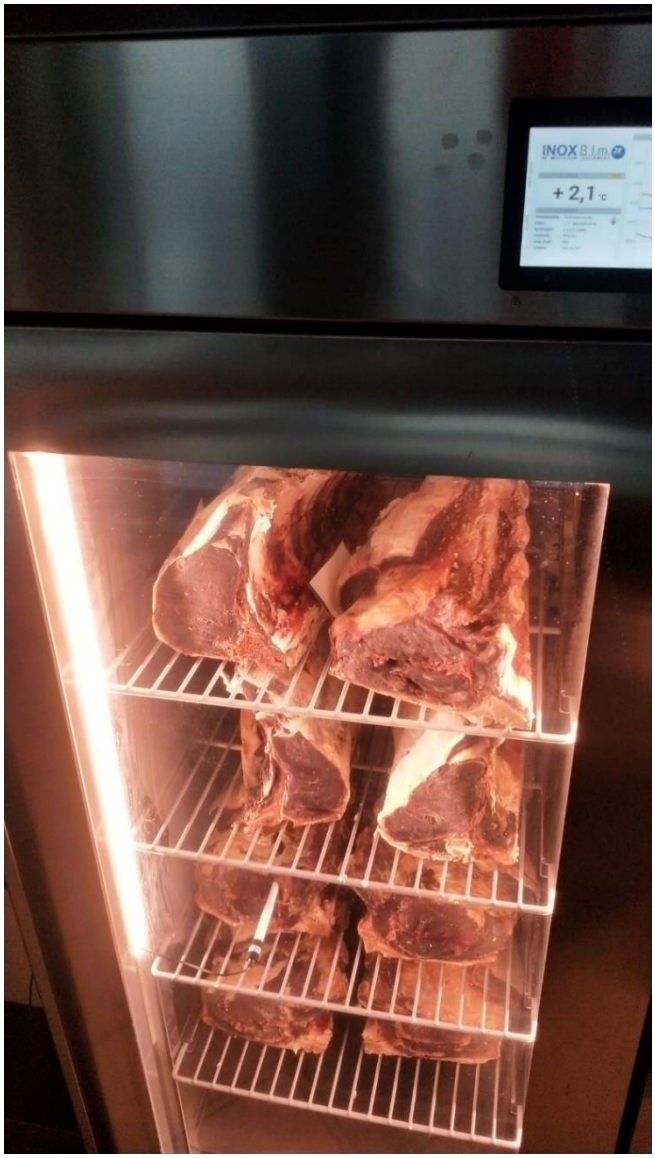
[29] *The effect of post-mortem aging on meat flavor quality in Brangus beef. Correlation of treatments, sensory, instrumental and chemical descriptors*. Spanier A.M.; Flores M.; McMilli K.W. Bidne T.D. 1997

[30] *Water-soluble precursors of beef flavour. Part II: Effect of post-mortem conditioning.* Koutsidis G., Elmore J. S., Oruna-Concha M. J., Camp M.M., Wood J. D., Mottram D. S. 2008.

[31] According to a research, the main responsible for the umami flavour mentioned above is the high level of glutamate in the pieces of meat subjected to maturation. *Effects of dry-aging on meat quality attributes and metabolite profiles of beef loins*. Kim, Y. H. B., Kemp, R., & Samuelsson, L. M. 2016

salty, and bitter) to expand and complement the flavors. Actually, it is regarded as one of the five basic tastes itself[32].

Dry-aging also benefits the aroma of the meat itself, helping to reduce the presence of microorganisms responsible for aromas considered "unpleasant", especially present in the meat of grass-fed cattles[33]; in addition to this, the oxidation of lipids and other microbial activities bring that characteristic fragrance of *dry-aged meat*[34].



[32] *Science of umami taste: adaptation to gastronomic culture*. K.Ninomiya. 2015
[33] *Elucidating mechanisms involved in flavor generation of dry-aged beef loins using metabolomics approach*. D.Setyabrata; B.R.Cooper; T.J.P.Sobreira; J.F.Legako;S.Martini; Y,H.B.Kim. 2020
[34] *Effect of Different Aging Methods on the Formation of Aroma Volatiles in Beef Strip Loins.* D.Lee; H.J.Lee; J. Won Yoon; M.Kim; C.Jo, 2021

• Weight loss

Weight loss is the "downside" of the aging process.

This is compensated by the increase in the price of the meat itself (obvious consequence of the fact that it goes through a (more or less) long maturation process).

Trying to establish an average weight loss of a piece of maturing meat is a difficult, if not impossible, task. The weight loss depends on several factors: duration of maturation, humidity and ventilation, and not least the presence of bone, since in the absence of this there will be a more pronounced loss of liquids[35].

[35] *Effects of dry age of bone-in and boneless strip loins using two aging processes for two aging times*. DeGreer SL, Hunt MC, Bratcher CL, Crozier-Dodson BA, Johnson DE, Stika JF. 2009

The weight loss of dry aged meat at 21 days normally approaches 20% (loss which occurs mostly in the first 7 days)[36].

The *temperature* and *duration* of aging are the factors that have the greatest impact on weight loss; definitely more than the other parameters[37], although other studies have also highlighted the role of *ventilation*[38].

Going on with the maturation, after reaching the peak of 21 days, the weight loss decreases more and more.

As an example: an experiment conducted in Inox Bim showed how a loin of heifer, aged for 113 days, had an overall weight loss of 22%[39].

Recent studies have demonstrated the properties of the external crust of matured meat and its potential as flavour enhancer[40]. This, in fact, lyophilized and pulverized, was examined by various *sensory panels*[41]. Pork especially benefits from the freeze-dried and grated rind, as it also improves its texture, reducing the drop in liquids during cooking[42].

Since making the crust usable as a flavouring is not yet cost-effective, a search for a cheaper method is underway, as it is considered a valid idea to reduce waste (and to obtain a natural and quality flavouring).

[36] *Effect of Two Organic Production Strategies and Ageing Time on Textural Characteristics of Beef from the Retinta Breed*. S. Garcia-Torres; A.Lopez-Gajardo; D.Tejerina; E.Prior; M.Cabeza de Vaca; A.Horcada. 2020

[37] In an experiment conducted on meat matured for 42 days, the weight loss was 22.5% at a temperature of 7˚C and 20.8% at 2˚C. *Effect of aging temperature on the Physicochemical Quality of Dry and Wet-Aged Beef*. F.M. Ferreira; S. Bertelli Pflanzer; A.P.S. Bernardo; C.L. Gomes. 2019

[38] *Assessment of dry-aged beef from commercial aging locations across the United States*. J.M. Lancaster; J.H.Smart; J.Van Buren; B.J. Buseman; T.M. Weber; K.Insausti; J.A. Nasados; B.Glaze; W.J. Price; M.J.Colle; P.D. Bass. 2022

[39] Weight considered with a part to be trimmed. Heifer loin preserved at 2˚C, 80% approx. RH, with a fixed presence of 0.1 PPM of ozone in the inner chamber. The weight dropped from 7,700kg to 6,000kg

[40] *Evaluation of functional and chemical properties of crust from dry-aged beef loins as a novel food ingredient*. S.Xue; D.Setyabrata; C.Bonham; Y.Kim. 2020

[41] *Utilization of the Crust from Dry-aged Beef to Enhance Flavor of Beef Patties*. B.Park; Hae In Yong; J.Choe; C.Jo. 2019

[42] *Quality Properties of Dry-Aged Beef (Hanwoo Cattle) Crust on Pork Patties*. J.Lee; H.Kim; K.Seol. 2022

• pH

The reduction of pH is essential for the good preservation of meat, as a low pH reduces microbial proliferation[43], main cause of rancidity[44]. Proof of a low level of pH is colour: when this is particularly dark, it is likely that the pH is above the warning levels, due to *deoxymyoglobin* and *mitochondrial activity*[45].

The pH value does not involve any variation in the loss of water (and therefore of weight) of the product [46].

Balancing low pH and as high a temperature as possible, they favour the softening of the meat[47] along with an optimal flavour. In fact, it has been shown in numerous studies that a pH of 6.2 or higher makes meat tender but at the cost of a much less pleasant taste[48].

Many research show how the oscillation of the pH between the values 5 and 6 is normal during the dry aging process.

The pH level could steadily drop in the first two weeks, and then stabilize, or rise slightly, in the following 2/3 weeks[49].

[43] *La carne*. Dipartimento Scienze Zootecniche -. Università di Sassari. 2011
[44] *Identification of Microbial Flora in Dry Aged Beef to Evaluate the Rancidity during Dry Aging*. S.Kim; Jong-Chan Kim; S.Park; Jinkwi Kim; Y.Yoon; Heeyoung Lee. 2021
[45] *Effects of postmortem storage time on color and mitochondria in beef*. Mancini, R.A.; Ramanathan, R. 2014.
[46] *Dry Aging of High Ultimate pH Beef*. F.A.Riberiro; S.K.Lau; N.Herrera; M.L.Henriott; N.Bland; J.Subbiah; C.Calkins. 2019
[47] *La carne*. Dipartimento Scienze Zootecniche -. Università di Sassari. 2011
[48] Research mentioned in *Ultimate pH effects on Dry Aged Beef Quality.* F.A.Riberiro; S.K. Lau; N.Herrera; R.Furbeck; M.L.Henriott; S.C. Fernando; G.A.Sullivan; J.Subbiah; C.Calkins. 2020
[49] *Assessment of Quality Indices and Their Influence on the Texture Profile in the Dry-Aging Process of Beef*. V.Bulgaru, L.Popescu, N.Netreba , A.Ghendov-Mosanu, R.Sturza.

Parameters

For dry aging, and it is easy to understand why, you need cabinets, cells, or other dedicated places. And it is also necessary to be able to control the various parameters that mark aging: temperature, humidity, ventilation, and duration in the first place, but also the activity of the germicide.

What may seem obvious, but it is better to specify in any case, is that different parameters lead to different processes and therefore to different results of maturation[50].

• Temperature

The cooling of the meat must be constant, in order not to hinder the activity of the enzymes necessary for the aging results[51].

A high temperature (around 6-7˚C) favours softening and enzymatic processes that improve the flavour; but, unfortunately, the other side of the coin is that such a high temperature favours bacterial proliferation, with the consequent effects of putrefaction and bad smells[52].

The tenderizing of the meat within the maturation process can be said to be more dependent on temperature rather than on other factors: an experiment showed that to reach the degree of tenderness reached at 5˚ in 14 days, it is necessary, with a temperature of 0,5˚, double the time, or 28 days[53]. However, it should be borne in mind that a low temperature prevents the emergence of moulds that can release mycotoxins [54].

Inox Bim, obviously except in special cases, suggests to dry age the meat with a temperature that is between 1˚ and 3˚C.

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[50] *The dry aged beef paradox: Why dry aging is sometimes not better than wet aging*. N.Terjung, F.Witte, V.Heinz. 2020

[51] *La carne*. Dipartimento Scienze Zootecniche -. Università di Sassari. 2011

[52] *Dry aging of Beef; Review*. D.Dashdorj, V.K. Tripathi, S. Cho, Y. Kim, I. Hwang. 2016

[53] *Aging of Beef. Standards and Guidelines.* PrimeSafe, Agency of the Government of the State of Victoria, Australia. 2017

[54] More specifically, temperature in between -0,5˚C and 3˚C. *Assessment of the mycological hazards associated with the dry ageing of red meat*. Olivier S. 2018

• Humidity

Water accounts for about 75% of the weight of the meat. Although it is important to emphasize that there are three distinct types of water inside the meat:

- *Preformed water*, originating from water or ingested food. This, in turn, is divided into "*free*" water and "*bound*" water. Free water, as the word implies, has no connection, and can evaporate. This moves to the surface of the maturing meat by *diffusion*[55].

The bound water, on the other hand, is crystallized water. This does not evaporate except at high temperatures. However, it does not favour bacterial proliferation.

- M*etabolic* water, derives from biochemical reactions brought about by the digestion of food molecules (whether they are carbohydrates, proteins or fats)[56].

This evaporates in more modest quantities, and much more slowly, than *free water* [57]

By making sure that the meat loses some of its liquids, we will have a loin with a lower weight than when purchased, but a much more *concentrated* flavour[58], reaching the ideal *peak* around the twenty-first day[59]. The low hydration of the surfaces (coupled with the temperature) prevents bacterial colonies from expanding too quickly[60]. An example is the substantial reduction of *E. coli*, one of the most common bacteria in the butchery and catering sector in general[61].

The lower relative humidity means a more rapid loss of liquids at the beginning of the aging process (in the first 7-10 days); however, this does not significantly affect the overall fluid loss, nor the chemical processes from which the flavors arise. It is safe to say that the *rate of fluid loss does not affect the quality of the meat*[62].

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[55] *Encyclopedia of Meat Science: Drying*. Lewicki, P.P. 2004.
[56] *La carne*. Dipartimento Scienze Zootecniche -. Università di Sassari. 2011
[57] *Drying dynamics of meat highlighting areas of relevance to dry-aging of beef*. S.Álvarez; C.Álvarez; R.Hamill; A.Mullen; E.O'Neill. 2021
[58] *Keys to Good Cooking: A Guide to Making the Best of Food and Recipes*. H.McGee. 2009
[59] *Assessment of Quality Indices and Their Influence on the Texture Profile in the Dry-Aging Process of Beef*. V.Bulgaru, L.Popescu, N.Netreba , A.Ghendov-Mosanu, R.Sturza.
[60] *Dry aging of Beef; Review*. D.Dashdorj, V.K. Tripathi, S. Cho, Y. Kim, I. Hwang. 2016
[61] *Aging of Beef. Standards and Guidelines.* PrimeSafe, Agency of the Government of the State of Victoria, Australia. 2017
[62] *Effects of Relative Humidity on Meat Quality in Dry Aged Beef*. F.A.Ribeiro; Soon K.; L.Morgan; L.Henriott; N.J.Herrera; N.A.Bland; J.Subbiah; C.R.Calkins. 2020

A visible development of mould on the meat during dry-aging can be an indication of water activity (aW), a value closely related to relative humidity, higher than 0.80[63]. Keeping the relative humidity rate within an acceptable range, all other conditions being equal, will avoid this danger.

The scientific literature is almost unanimous in attesting the relative humidity rate for the success of maturation between 75% and 80%, although there are still few experiments with which a significantly lower or higher rate has been tested[64].

• Duration

As a rule, beef is matured for a period ranging from 14 to 28 days. Although longer periods are increasingly taken into consideration, the scientific literature does not agree in the judgment on long aging; these bring changes to the flavour, so it is subjective to speak of enhancement[65].

So, basically, they modify the flavour, not necessarily making it better.

Before 14 days, there are no significant enhancements neither as it concerns aroma, nor taste, nor consistency[66].

Several research show that the peak of flavour in beef is reached around 21 days of maturation[67] [68]*.*

A study shows how a maturation period of between 21 and 28 days positively affects the development of those processes that lead to the intensification of the typical aromas of matured meat [69].

It can be said that the recommended maturation period is between two and four weeks[70].

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[63] *Intrinsic and extrinsic parameters of food that affect microbial growth. Modern Food Microbiology*. J.M.Jay. 1986
[64] *Dry aging of Beef; Review*. D.Dashdorj, V.K. Tripathi, S. Cho, Y. Kim, I. Hwang. 2016
[65] *Dry aging of Beef; Review*. D.Dashdorj, V.K. Tripathi, S. Cho, Y. Kim, I. Hwang. 2016
[66] *The influence of forage diets and aging on beef palatability*. Jiang, T.; Busboom, J.; Nelson, M.; O'fallon, J.; Ringkob, T.; Rogers-Klette, K.; Piper K. 2010
[67] *Dry versus wet aging of beef: Retail cutting yields and consumer palatability evaluations of steaks from US choice and US select short loins*. Smith R.D., Nicholson K.L., Nicholson J.D.W., Harris K.B., Miller R.K., Griffin D.B., Savell J.W. 2008
[68] *Effects of post-mortem aging time and type of aging on flavor, tenderness, color, and shelf-life stability of beef loins with marbling between Slight to Small*. Lepper-Blilie A.N., Berg E.P., Buchanan D.S., Berg P.T. 2012
[69] *Mechanisms and strategies to tailor dry-aged meat flavour*. Renyu Zhang; M.Yoo; A.Ross; M.Farouk. 2020
[70] *Postmortem Aging of Beef with a Special Reference to the Dry Aging*. M.I.Khan; S.Jung; K.Chang Nam; C.Jo. 2016

Around the twenty-first day of maturation, moulds of the genus *Thamnidium* begin to appear on the fatty parts. Their enzymes can penetrate the connective tissue and attack it, softening and flavouring the meat[71].

Dry aged meat, once its oxidized parts have been trimmed and cut into portions, can be displayed for sale for a few days without undergoing any changes in colour or appearance in general. This was proven by an experiment performed with matured meat exposed to 2˚C. The first signs of oxidation appeared after three days[72].

It does not seem there is a maximum time limit for maturation. What is certain is that, beyond a certain threshold, there are no further improvements, due to the maximum amount of unbound water that can evaporate, both to the protective crust on the outside which begins to become more coriaceous[73], and to a greater oxidation of lipids [74].

If we really wanted to identify a point of *maximum maturation*, a point beyond which it is not possible to enhance flavour or consistency, this could be identified *between 50 and 80 days*[75]. This estimate was confirmed by a more recent experiment, in which beef, aged at 1°C and about 80% relative humidity, began to rancid around the eleventh week[76].

• Ventilation

It is essential to dose the ventilation for the dry aging process, as little air does not allow the meat to release the necessary moisture creating an ideal situation for the proliferation of molds and bacteria[77]. On the contrary, too accentuated ventilation may dry the

[71] *Aging of Beef. Standards and Guidelines.* PrimeSafe, Agency of the Government of the State of Victoria, Australia. 2017
[72] *Color and Lipid Stability of Dry Aged Beef During Retail Display*. F.A.Riberiro; S.K. Lau; N.Herrera; M.Henriott; N.Bland; S. Bertelli Pflanzer; J.Subbiah; C.Calkins. 2019
[73] *The dry aged beef paradox: Why dry aging is sometimes not better than wet aging*. N.Terjung, F.Witte, V.Heinz. 2020
[74] *Comparison of meat quality, fatty acid composition and aroma volatiles of dry-aged beef from Hanwoo cows slaughtered at 60 or 80 months old*. Utama, D. T., Kim, Y. J., Jeong, H. S., Kim, J., Barido, F. H., & Lee, S. K. 2020.
[75] *Dry aging Beef*. N.Perry. 2011
[76] *Identification of Microbial Flora in Dry Aged Beef to Evaluate the Rancidity during Dry Aging*. S.Kim; Jong-Chan Kim; S.Park; Jinkwi Kim; Y.Yoon; Heeyoung Lee. 2021
[77] *Franklin Steak: Dry-Aged. Live-Fired. Pure Beef*. J.Mackay; A.Franklin. 2019

product[78]. There must be constant air circulation, which is essential for putrefactive bacteria not to intervene[79].

To make the circulation of air easier, it is advisable to separate the pieces of meat, so that all exposed surfaces can benefit from this[80].

It is equally important to maintain a constant speed of ventilation, especially in the early stages of the dry aging process[81].

Particularly accentuated ventilation (between 2.5 and 5 m/s) could affect the texture of the meat, making it less soft[82]. However, this is not the case with the INOX BIM climatic cabinet, as the ventilation is between 1 and 1.5 m/s.

In addition to this, a too "aggressive" level of ventilation leads to a greater weight loss, due to the loss of liquids, as well as a greater part will have to be trimmed afterwards[83].

• Ozone

Although aging involves a natural oxidation process, this is not overly accelerated by the presence of ozone. Ozone darkens the external part of the meat, but usually not the fat[84], which takes on a bright white colour with proper aging[85].

An experiment showed how a gradual ozonation up to 72 PPM (and therefore much greater than those recommended) did not lead to oxidation of the product, compared to a

[78] *Dry aging of Beef; Review*. D.Dashdorj, V.K. Tripathi, S. Cho, Y. Kim, I. Hwang. 2016
[79] Intervista a Mark Pastore, presidente della "Pat LaFrieda Meat Co Inc.". Citato in *The Food Lab: Can I Dry Age Beef at Home?*. J.Kenji Lopez-Alt, 2019
[80] *Guidelines for U.S. dry aged beef for international markets*. Meat Export Federation of USA. 2014.
[81] *Dry aging of Beef; Review*. D.Dashdorj, V.K. Tripathi, S. Cho, Y. Kim, I. Hwang. 2016
[82] The effect of a too high level of ventilation, according to the author, affects the bacteria population and, consequently, the proteolisis. *Changes in microbial composition on the crust by different air flow velocities and their effect on sensory*
properties of dry-aged beef. Lee, H. J., Yoon, J. W., Kim, M., Oh, H., Yoon, Y., & Jo, C. 2019.
[83] *Effect of subprimal fabrication and packaging methods on palatability and retail caselife of loin steaks from lean beef*. Miller, M. F., Davis, G. W., and Ramsey, C. B. 1985
[84] *Effects of Ozone on Beef Carcass Shrinkage, Muscle Quality and Bacterial Spoilage*. G.G. Greer; S.D.M. Jones. 1989
[85] Experiments carried out privately at Inox Bim.

good reduction of the bacterial load[86]. A reduction in the bacterial load, albeit limited, was also recorded during a very low concentration ozone: 0,0006 PPM[87].

However, it must be specified how ozone allows the containment of the bacterial load during treatment, but does not prevent proliferation once the aforementioned treatment is concluded[88].

Ozone also influences weight loss, although it seems negligible, or in any case not particularly incisive[89].

Inox Bim suggests, in case the machine features the ozone generator with probe, to keep a level of 0,10 PPM.

Please note that the above is the PPM value that the probe detects inside the inner chamber. Anyway, a higher quantity of ozone will actually be generated, as animal fat is an excellent catalyst. To put it simply, the probe will detect *residual ozone*.

[86] *Antimicrobial action and effects on beef quality attributes of a gaseous ozone treatment at refrigeration temperatures*. F. Coll Cardenas; S.Andrés; L.Giannuzzi; N.Zaritki. 2011

[87] *Ozone treatment of chilled beef. 1. Effect of low concentration of ozone on microbial spoilage and surface colour of beef*. G.Kaess, J.F.Weidemann. 1986

[88] *Effects of Ozone on Beef Carcass Shrinkage, Muscle Quality and Bacterial Spoilage*. G.G. Greer; S.D.M. Jones. 1989

[89] An experiment showed that ozone at 0.03 PPM in 9 days led to a weight loss greater than 10.6g per kg in comparison to the control group. The dry aging was carried out at 1,6˚C, 95% RH. *Effects of Ozone on Beef Carcass Shrinkage, Muscle Quality and Bacterial Spoilage*. G.G. Greer; S.D.M. Jones. 1989

Summary

In conclusion, the summary of the parameters that Inox Bim suggests for beef dry aging.

Once again, and we cannot stretch this concept enough, what we gathered are nothing more than generic suggestions. Since the aging process has different data to consider, there cannot be a single *recipe*.

Temperature: 2˚C (±1˚C)

Relative Humidity: 78% (±5%)

Ventilation: fans one minute ON, three minutes OFF

Ozone: 0,10 PPM (if there is an ozone probe). 20 seconds of ozone generation every 10 minutes (with the basic version)

Dry aging of other types of Meat

As mentioned at the beginning, although dry aging is mostly used for beef, there is no shortage of examples of how to do it on other types of meat.

• Pork

Pork can also benefit from the dry aging process, which has the potential, just like in beef, to mature new flavours, without contraindications relating to its organoleptic qualities[90].

Given the young age at which the animal is slaughtered, pork usually needs shorter times than the aging of the beef. Furthermore, some pieces of pork (such as shoulder) have a faster loss of liquids than similar cuts of bovine[91], and a greater speed, compared to ruminants, of the oxidation of intramuscular fat[92].

As an example: the leg can reach the peak of tenderness in four days, the sirloin in nine[93].

Lean pork is ideally excellent to be dry-aged, as a dry-age period would make it softer, and therefore more palatable to the consumer[94].

A study has documented effective maturation of pork between 14 and 21 days at 2˚C, and even up to 40 days, at 2˚C and 80% relative humidity[95].

This kind of meat does not need any long period of dry aging (Inox Bim suggests from 4 to 9 days depending on the cut). However, in case you want to try a longer maturation, the favourable aging conditions do not increase the harmful bacterial flora. The only microorganism that seems to benefit from a correct process is *D. Hansenii* mould, which has beneficial effects on tenderness and taste[96].

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[90] *Effect of Dry-Aging on Quality and Palatability Attributes and Flavour-Related Metabolites of Pork Loins*. D.Setyabrata; A.D.Wagner; B.R.Cooper; Y.H.B.Kim. 2021

[91] *Palatability and hygiene characteristics of dry-aged pork and optimization of dry-aging period*. O.Seong Nam; I.Park. 2020

[92] *The Storage and Preservation of Meat*. Y.L. Xiong, in *Meat Science*, 2017

[93] https://www.thepigsite.com

[94] *Is Dry-Aging for Pork Relevant to Consumers?* M.Canavari; R.Wongprawmas; D.Biasco. 2017

[95] *Quality Improvement of Pork Loin by Dry Aging*. C.Woo Lee; J.R.Lee; M.Kyu Kim; C.Jo; K.Haeng Lee; I.You; S.Jung

[96] *Characterization of the microbiota and chemical properties of pork loins during dry aging*. A.Endo; R.Koizumi; Y.Nakazawa; Y.Shiwa; S.Maeno; Y.Kido; T.Irisawa; Y.Muramatsu; K.Tada; M.Yamazaki; T.Myoda. 2020

However, it is advisable to use ozone in abundant concentrations (0.5 PPM) for long aging, as there is a risk of a rapid proliferation of E. Coli (but not of Salmonella and Listeria)[97].

• Sheep

Also, for sheep, the general rule applies that the younger an animal is, the less the dry aging will last. A dairy goat, for example, does not need a maturation that goes beyond 3 days. A mutton with more than 6 months of life, however, may need about 5 days.

The sheep will lose weight during the maturation period, the same as the beef. The quantity depends, among other things, on age, anatomical piece, and the presence of fat (inversely proportional to the loss of fluids)[98].

Long maturation (up to 21 days) for sheep over 4 years of age has recently become popular in Australia, with satisfactory results, and the opening of a market "niche"[99]. This was supported by a scientific study, which demonstrated greater consumer satisfaction for "aged" mutton, dry-aged at 1.5°C (± 1°C), at a relative humidity of less than 85%, for periods ranging from two to five weeks[100]. Yet another study successfully performed maturation of adult mutton at a temperature between 1°C and 2°C and a relative humidity rate between 80 and 85% for periods longer than two weeks[101].

A recent study has shown that a piece of lamb meat aged 7 days at 80% RH was preferred by a sensorial panel to a similar piece of meat aged in vacuum or with a lower humidity[102].

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[97] *Palatability and hygiene characteristics of dry-aged pork and optimisation of dry ageing period.* O.Nam; I.Park. 2020
[98] *Effect of carcase characteristics and sheep breeding values on the yield of dry- and wet-aged multipurpose merino cull ewe meat*. M.Hastie; R.Jacob; M.Ha; G.Hepworth; D.Torricod; H.Ashmana; R.Warnera. 2021
[99] https://www.abc.net.au/news/2016-08-19/mutton-makeover-dry-aged-meat-back-in-fashion-in-australia/7762068
[100] *Product Design to Enhance Consumer Liking of Cull Ewe Meat*. M.Hastie; H.Ashman; D.Lyman; L.Lockstone-Binney; R.Jacob; M.Ha; D.Torrico; R.Warner. 2021
[101] *Combining hierarchical clustering and preference mapping differentiates consumer preference for dry aged mutton*. M.Hastie; H.Ashman; G.Hepworth; R.Jacob; M.Ha; D.Torrico; R. Polkinghorne; R.Warner. 2021
[102] *Characterization of dry aged lamb eating quality at different aging conditions and cooking methods*. X.Wang; C.Ren; L.Chen; Y.Bai. 2022

• Poultry

Poultry is, by itself, a tender meat that does not need any aging. Generally, two processes can be carried out simultaneously for chicken and turkey: aging and salting, both dry.

As for the duck, which is not popular as food in the same way all over the world (and therefore it is not easy to find notions about dry aging), it is generally recommended to hang it at 2˚C for a period between five and seven days[103].

• Boar

The boar, being a wild animal, has less fat than the pork, with a more pronounced presence of muscle fibres. A research suggests two weeks at + 2˚C for the wild boar aging[104]. Another website has indicated a wider temperature range (in between 0 and 4˚C), with a high relative humidity (in between 85 and 90%)[105].

• Venison

A non-scientific experiment conducted by an American site specializing in hunting and fishing, compared venison, aged for a different period, between 2.5˚ and 3.5˚C and between 75% and 85% of relative humidity. The experiment revealed how venison aged for less than 7 days did not satisfy the examiners; meat matured for a week tasted satisfactory and, the one with a higher rating, was meat matured for two weeks[106].

[103] https://www.ducks.org/hunting/waterfowl-recipes-wild-game-cooking/dry-aging-versus-brining
[104] *The effect of chilled storage on the quality of meat from the feral wild boar (Sus scrofa)*. A.Ludwiczak; D.Kulig; J.Składanowska-Baryza; M.Bykowska-Maciejewska; T.Tarnawski; M.Stanisz. 2018
[105] https://www.modomirino.it/marinatura-del-cinghiale.html#:~:text=Il%20PH%20della%20carne%20torna,e%20la%20putrefazione%20della%20carne.
[106] The meat aged for two weeks had more satisfactory results than the meat aged for three or four weeks. https://www.fieldandstream.com/story/hunting/venison-taste-test-how-long-should-you-hang-your-deer/