FoMRHI Comm 2151 **Mimmo Peruffo**

Vincenzo Capirola and the taper of gut strings: practical tests and results

Vincenzo Capirola (*c.*1517) wrote in the introduction to his lute manuscript, a chapter entitled: 'Secreto da ligar le corde sul lauto' (secret of tying the strings on the lute).[1] Capirola explains how to tie the strings of the lute properly, starting from the fact that, as he sees it, they are fatter at one end than the other. Vincenzo points out in particular that tying the fatter end of the string to the bridge, flatter notes are produced on the frets as you go up the fingerboard, and vice versa. Capirola's method may be summarised as follows: you put the thick end of courses 5 and 6 on the bridge; and the thin end instead for the fourth, third and second courses.

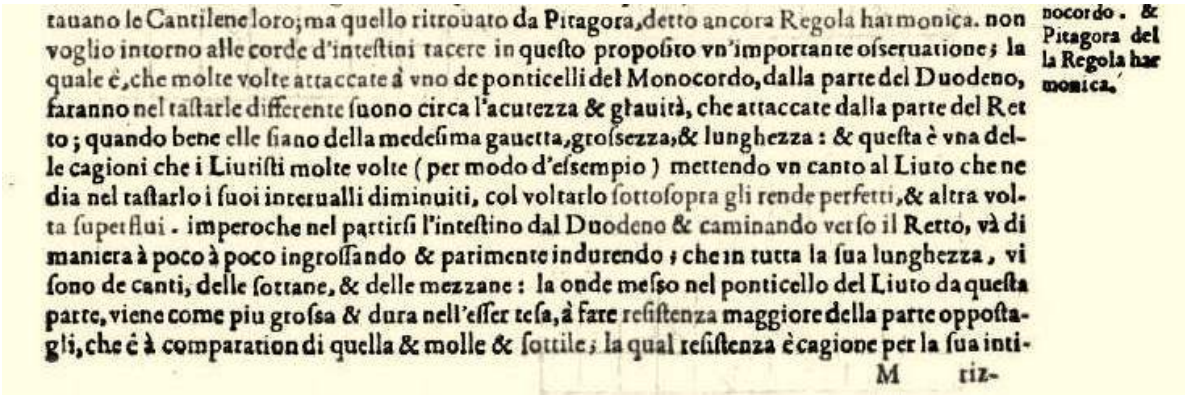
Capirola emphasises that using the Munich strings this problem does not occur. It is unclear whether it refers only to treble strings or to the middle and bass strings too. Munich strings (Minikins) are also described by Adrian Le Roy[2] and John Dowland[3] and are specifically strings for the higher courses. Capirola points out that the difference in thickness between the two ends of a string are more evident in the thinner ones than in the thicker ones and especially in that commercial variety called *ganzers* and which belong exclusively to the middle register. The problem of tapering therefore arises in all strings except those manufactured in Munich.

The evidence that *ganzer* strings might manifest more clearly the inequality of gauge along their length militates against the hypothesis that they were made of silk and woven with cord-making techniques, 'cordonetto' (twined string) does not by its nature have one end larger than the other.

It is interesting to note that no other method for lute of earlier or later centuries ever highlighted the question of alleged taper: this is certainly not a negligible detail. It is therefore surprising that the many others who subsequently wrote treatises or tablatures ever mentioned them. The questions that arise are as follows. Was what Vincenzo described a common problem for all the luthiers of his time? Did the problem of the alleged taper of the strings also exist in the time of Dowland and Mace? And if it was a problem, why is he the only one talking about it?

The Spaniard Juan Bermudo at one point in his treatise seems to refer to this problem: in order to achieve a correct pitch set-up of strings the vihuela bridge must be glued not at right angles to the axis of the soundboard but slightly angled so that the vibrating length of the bass is slightly greater than the trebles. Bermudo explains, however, that this is done to compensate for the thickness of the knot produced by the (large) sixth-course string at the bridge, which produces a significant shortening of the vibrating length. Without this, the fretted notes produced by the sixth and fifth courses would be raised in pitch compared to those of the other higher strings.[4]

Capirola's instructions have therefore led some researchers to conclude that the strings for lute indeed had a conical profile, that is, with a diameter that gradually reduces along the length of the string, even believing that this was a deliberate construction technique. But what about the intestine which is the starting point of the process? Is it cylindrical or conical? Here's Vincenzo Galilei[5]



tauano le Cantilene loro; ma quello ritrouato da Pitagora, detto ancora Regola harmonica. non voglio intorno alle corde d'inteſtini tacere in queſto propoſito vn'importante oſſeruatione; la quale è, che molte volte attaccate à vno de ponticelli del Monocordo, dalla parte del Duodeno, faranno nel taſtarle differente ſuono circa l'acutezza & grauità, che attaccate dalla parte del Retto; quando bene elle ſiano della medeſima gauetta, groſſezza, & lunghezza: & queſta è vna delle cagioni che i Liutiſti molte volte (per modo d'eſſempio) mettendo vn canto al Liuto che ne dia nel taſtarlo i ſuoi interualli diminuiti, col voltarlo ſottoſopra gli rende perfetti, & altra volta ſuperflui. imperoche nel partirſi l'inteſtino dal Duodeno & caminando verſo il Retto, và di maniera à poco à poco ingroſſando & parimente indurendo; che in tutta la ſua lunghezza, vi ſono de canti, delle ſottane, & delle mezzane: la onde meſſo nel ponticello del Liuto da queſta parte, viene come piu groſſa & dura nell'eſſer teſa, à fare reſiſtenza maggiore della parte oppoſtagli, che è à comparation di quella & molle & ſottile; la qual reſiſtenza è cagione per la ſua inti-

nocordo. & Pitagora della Regola harmonica.

M tiz-

According to Galilei, the small intestine of sheep (which has an average length of between 20 and 25 metres) therefore has a conical profile: it starts from the upper part with a certain diameter that gradually increases as we proceed towards the blind intestine.

On the monochord described by Galilei, however, a lute string would have been used presumably a metre or a little more in length: was the degree of taper so evident here? Had he measured it or simply deduced it by carefully observing the two ends of the string? Or had he deduced it because the proportions of the frets and the notes consequently produced on the monochord were not consistent? There are very few other references about the difference in the thickness of one end of the string and the other. Leopold Mozart is a good example but we have already jumped ahead by centuries.[6]

As was said, the introduction of the concept of 'taper' of ancient gut strings has only taken hold in the last two decades.[7, 8] In the very rare treatises or methods that have mentioned it, apart from Capirola and Vincenzo Galilei, they refer only to the musical string, not to the natural characteristics of the fresh intestine.

According to the present writer it is a risky conclusion to go to introduce the concept that old strings had or were made with a conical profile, trusting in the only historical source that speaks of it in a period of at least 250 years before the disappearance of the instrument (Galilei actually refers to the monochord).

There are other explanations for this fact: the manual polishing system used at the time, for example, which was carried out by rubbing the well dried strings, still stretched on the frame, with natural substances of an abrasive nature such as pumice, shave grass, etc. smeared with a little oil. The purpose of this operation was to eliminate as much as possible the roughness of the surface while *trying to interfere the bare minimum, i.e. avoiding changing the size of the diameter producing by the first polishing*. It is very difficult, in fact, working only freehand, not to to ovalise the string, scratch it too much and / or make it unequal in some places to the detriment of others: the string becomes hopelessly false or weak; this is a flaw.

Not for nothing were the tests for the control of possible falseness of the (very expensive) strings widely described in almost all the treatises of those centuries until the beginning of the twentieth century.

The concept of the amount of polishing is very important and must be well grasped by the reader who has never seen or who does not know how to *really* make a gut string. Even today, with modern rectifying or grinding machines, it is essential that the polishing of a gut string is carried out in such a way that at the first appearance of uniform smoothness in the whole string you stop immediately the grinding process and accept the nearest commercial diameter that comes out (today's strings are often found with a surplus of little-used diameters of string but which cannot be reduced any further). In fact, a string that is too smooth, as soon as it is put into tension, begins to 'peel' or tousle quickly if not actually break, due to the excessive amount

of surface fibres damaged by the process itself, by hand or by machine. This is all the more so when it comes to the thin strings of the top course, where the less you interfere, the better.

However, the researchers also introduce the hypothesis that a certain gradient of taper could be something expressly produced by the ancient string makers, and not a fact merely related to the nature of the gut as raw material. How a regular and even taper could be manually realised remains for the present writer – himself a string maker - a mystery. We must logically admit something not allowed: such an operation inevitably results in excessive removal of material in the section you want to have a lesser diameter, and before that even, a string thus made frays and breaks as soon as it is put under tension on the instrument.

This hypothetical taper cannot therefore be achieved by means of forced and progressive 'sanding' from one end of the string to the other: alternatively, it was also thought that it could possibly be achieved by pairing together all the larger ends of each gut that made up the roped structure of the string.[8] It would also seem here that the proponents of this theory do not have practical knowledge of the processing of the gut and the level of implausible problems that a string maker would face.

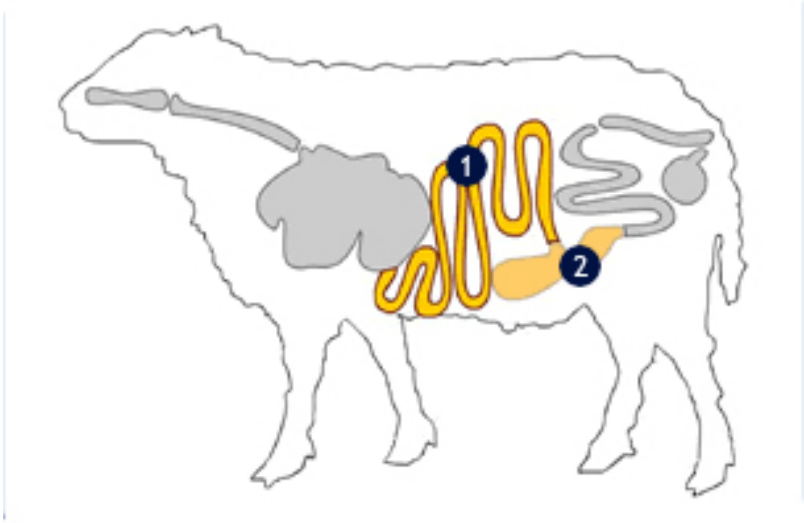
It is also necessary to consider that we are talking about the 16th and 17th centuries, when certain measuring and processing instruments were not available: for example, how in the sixteenth, seventeenth and eighteenth centuries could they measure a progressive variation in taper to reach 2% (as suggested by the researchers for the sixth string of the lute) of increase in diameter that must be found along the length of string, necessary for the lute, without the aid of a micrometer? And how they would then be able to reproduce exactly batches of strings with the same dimensional characteristics remain unanswered questions - *even for today's strings.*

But can such a process potentially be carried out? Theoretically yes but, as I have just said, there was no way at the time to predict and reproduce the desired taper gradient because they did not have suitable measuring instruments to be able to detect it with the precision required for music. And then, because gut is a natural product not standardised at all, it is therefore not totally predictable how the finished string, dimensionally. This aspect of low predictability still exists today and is considered to be one of the main problems that arise in the production of gut strings.

That the taper of a string could be something expressly desired by the string makers of the time is, moreover, denied by Capirola himself, who emphasises the fact that the difference in thickness between the two ends constitutes *a problem, not an advantage*: it is precisely for this reason that he provides the advice to use the strings from Munich, where available, and is at the same time forced to develop his own special '*secreto*' designed to limit the problems.

But is it true that the sheep intestine is conical? What conicity gradient are we talking about? These are important questions that necessarily involve *a practical verification.* We therefore performed a series of tests starting from a single sheep intestine (presumably lamb) 7.2 metres long.

As mentioned, the entire length of a small intestine of adult sheep varies between 25 and 30 metres (the total length also depends on the breed, not only on age) but in lamb it is generally shoter, at 15-20 metres.



source:
http://www.arecchibudella.com/site/vendita-budella-italia-calabria-sicilia/vendita-budella-di-ovino.html

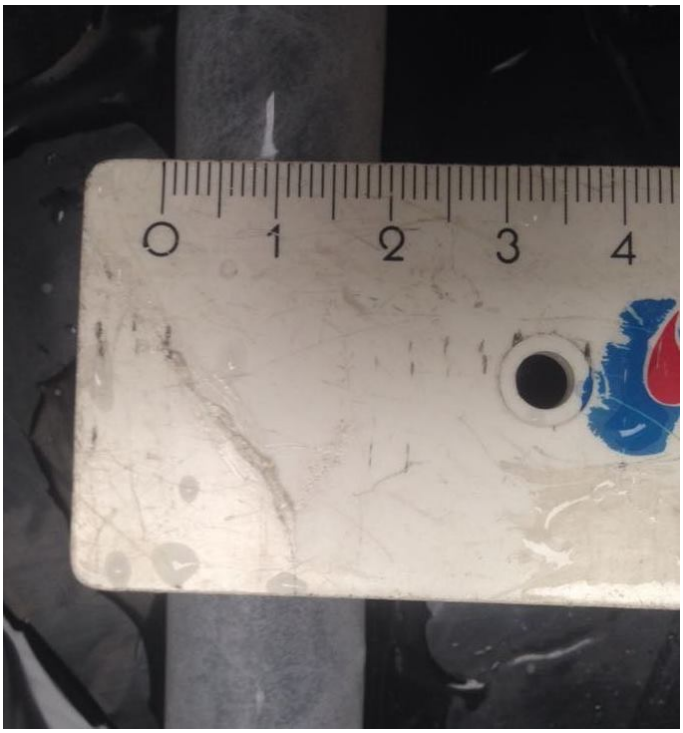
With regard to the measurement of the diameter at a given point in the intestine, the following observation must be made: the intestine does not behave like an inner tube of a bicycle that swells it the more it grows. Rather, a intestine filled for example with water under pressure will swell until it reaches its maximum diameter beyond which it cannot go without breaking. The method of measuring the official diameter in fact provides that the casing is filled with water and passed through semicircular holes or slots in a simple plastic device (called a gauge) of increasing calibre until you find a close fit.

Variable gauge to determine the diameter of the gut
(source: http://www.cds-hackner.de/app-schafssaitlinge.aspx?cls=02)

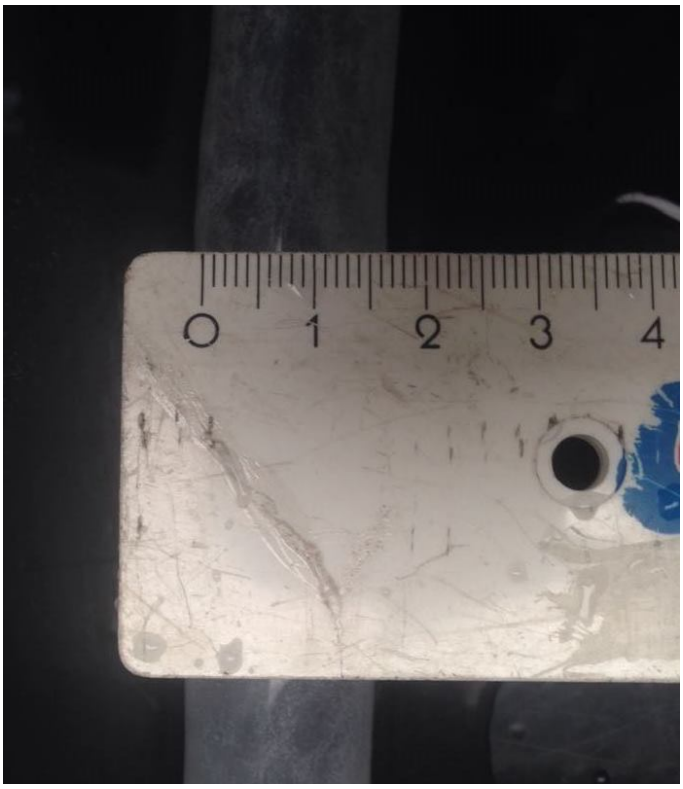
Commercially speaking sheep intestines are sold according to internationally standardised diameter ranges such as 16-18 mm; 20-22 mm; 24-26 mm and finally 28 +.

The ranges of smaller diameters typically apply to either younger animals or adult animals of particular breeds.

A further detail should be made clear: there is no ‘upstream’ selection between young animals or adults, and males or females before slaughter in today's slaughterhouses, as in the past, such that we could know to which animals the intestines had belonged after slaughter. The animals are slaughtered according to a random logic depending on the order of arrival at the slaughterhouse of the poor creatures. The selection is therefore made only after slaughter: the guts are carefully measured one by one by means of gauge, mixed according to their diameter and collected in bundles marked with one of the groups of diameter ranges mentioned above; for example 16-18 mm. For our tests we used a commercial calibration casing of 18-20 mm which is the smallest calibre that can be used for sausages (the 14-16 mm range exists but is usually discarded because it is too small for any sausage). The measurements we find are about 19-20 mm at one end and about 16-17 mm at the other. The total length of our thin sheep gut was 7.20 metres.



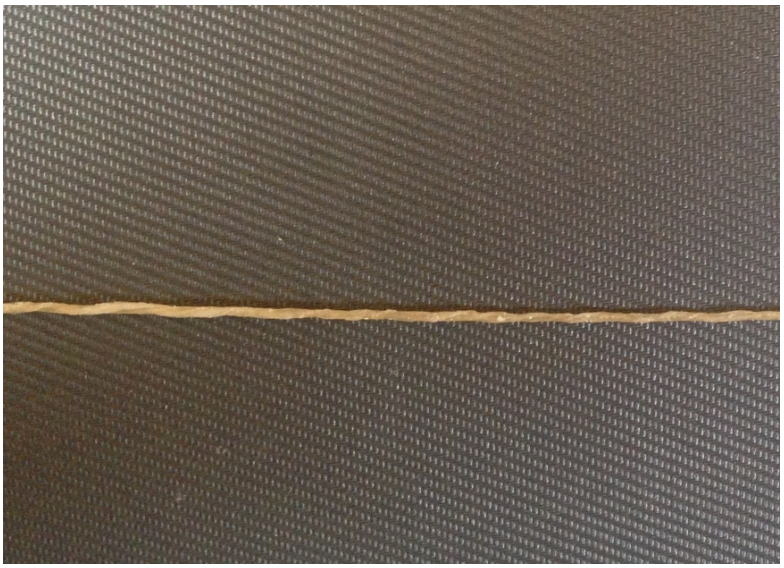
Measuring the end with larger diameter: about 19 mm



Measurement at the thin end: 17 mm

The taper of the intestine is therefore confirmed but here we have the surprise (which makes the Galilei's consideration about the problems highlighted on his monochord irrelevant): once twisted whole (that is, not cut in advance in strips) to make a string that acts as a lute treble you realise that the diameter of the string is instead *totally regular,* with a slight variation around the average value by virtue of the notable surface roughness.

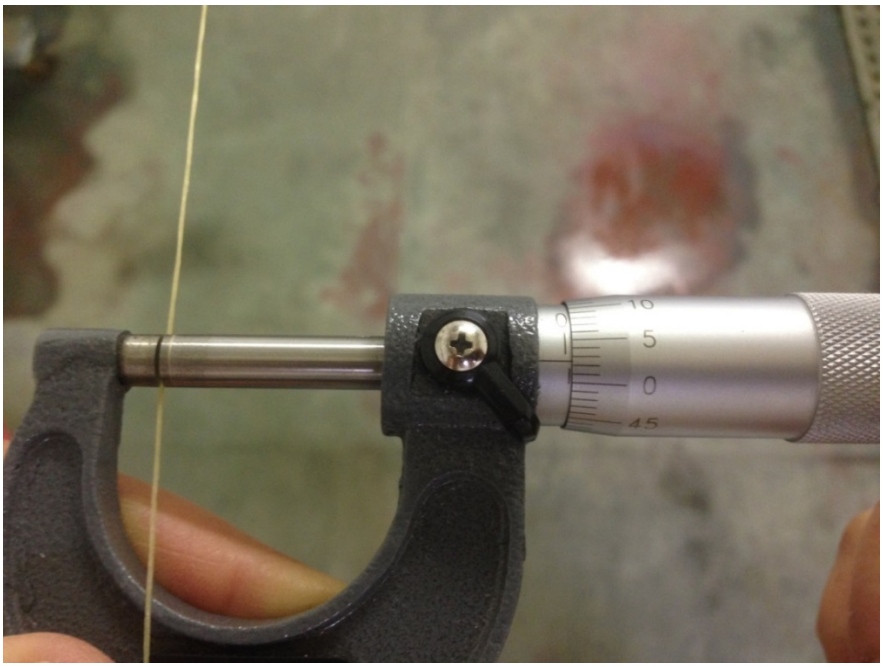
The use of a single gut to make the treble string of the lute comes to us from Athanasius Kircher: in fact, he points out that to make the lute treble contemporary (mid-17th century) Roman string makers - use a single whole lamb gut about seven to eight months of age.



Appearance of the string made in our experiment

Our measurements, made of course with a micrometer, showed in fact an oscillation in diameter in its entire length between 0.52 and 0.54 mm only, with no evidence of progressive increase or decrease of the calibre (which would have been a sure proof of the taper of the finished string). The tests were also carried out with other intestines of smaller diameter in the fresh state that we were able to find: in spite of the usual conicity of the intestine the string produced is always substantially constant in diameter along its entire length. The diameter range obtained with a single smaller lamb intestine was 0.33-0.44 mm.

Measurement carried out on one end of the dried string of 7.2 m: 0.53 mm unpolished



Measurement carried out on the opposite end of the dried 7.2 m string: 0.52 mm unpolished

Conclusions

The tests we carried out showed the following:

1) The sheep intestine – whatever breed or age is taken into account – is by its nature conical; this taper is not very noticeable to the eye except over several metres in length. The taper of the intestine is therefore not detectable in the case of a length of around 1 – 1.2 m, which is equivalent to the length of string that is normally put on a lute or monochord. In our case after 7 m in length an increase of only 3 mm in diameter is measured in the raw intestine. In a length of 1 metre or a little more the difference is therefore rather imperceptible, especially if appropriate measuring instruments are not available. It is clear that along the entire natural length of the small intestine, about 20-25 m, the difference is even more marked but here in the case of Capirola we are talking about that portion of length that will then be mounted on the lute and over which he might detect a certain difference in diameters between one end and the other.

2) The taper of the intestine does not affect the final diameter. This result is really surprising: it means that the growth of the diameter is due more to a simple phenomenon of progressive dilation of the intestine and relative thinning of its wall than to a real increase in diameter while keeping the thickness of its wall unchanged. The proof is given by the uniformity of the diameter of measurement along the dried string. We must conclude that what Capirola described must necessarily be taken with a pinch of salt, unless the animal biology of sheep of that time was radically different from today's. But this is a fanciful hypothesis (unless the sheep grew up around Chernobyl and have been subjected to genetic mutation!*).*

3) According to the practical evidence just described, the researchers' assertion that the gut strings of the time were of a conical nature both by nature and perhaps due to a particular processing technique introduced by the string makers of the time is invalid. Gut strings were produced not only for the lute but without distinction for any and every class of plucked and bowed instruments, fretted or not (and also for technical uses of other kinds): needs were therefore diversified. Producing a conical string by manual sanding is theoretically possible but would produce and an extremely fragile and inconsistent string. That in the sixteenth century they intentionally produced conical strings by orienting the fat ends of the guts all the same way is a purely speculative and meaningless conjecture both from a manufacturing and acoustic point of view: there is no control of the degree of taper obtained nor could it be measured with the high precision required.

   All the lutistic sources available today of our knowledge *that describe* this aspect of the gut strings in a period of time between 1507 and the end of the eighteenth century are reduced to only one: Capirola - and he treats it as a defect, so much so that he advises to use those of Munich as a better alternative.

   The term 'taper' or ‘conicity’ therefore seems a term not corresponding to the reality of the facts highlighted so far: the very few historical sources other than those of the lute are also limited to describing the difference in thickness between one end and the other of the string. This phenomenon can be attributed to several other causes such as a bad or inadequate sanding or polishing operation, which can very heavily affect in the constancy of the diameter in the entire length of the string.

4) The alleged taper effect - in the case of thicker strings that are made with more guts roped together - is much more limited due to the 'mediation' effect, due to the quantity and dimensional diversity of the paired guts used in order to reach (approximately) the particular diameter desired: therefore the greater the number of guts tied together, the greater the constancy of the final diameter, the lower also the degree of natural roughness of the rope.

I do not agree with what some researchers have supposed (ref 8, p 38) who say that the sixth string of Capirola's lute must show the maximum difference in diameter (read 'taper') between the two ends: the opposite is true. It is Capirola himself who confirms it to us: 'ma sapi che patise più le corde sotil che le grose et masime le corde da ganzer et altre che non fatte da monaco…'. (but know that the thin strings suffer more than the fat strings and most of all ganzer strings and others that are not made in Munich).

5) Athanasius Kircher documents for us that the lute trebles made in Rome around the middle of the seventeenth century were made of a single lamb gut about 7 or 8 months of age; the English traveller Skippon indirectly confirms this, writing that thin strings are made from a single gut.[9]

6) In the opinion of the present writer strings cannot be considered as conical: Capirola does not say that they are conical but only that one end is larger than the other. It is a different thing from saying they are conical, which would be a hasty conclusion. Considering the construction technique based on the whole lamb gut they could actually have by pure chance one end slightly larger than the other. To this must be added the phenomenon of fretting sharp that occurs when a string of a certain thickness is pressed against the keys, a phenomenon that is instead limited in paired octaves. The suggestion of tying on the large strings at the end which presents a thinner diameter therefore allows us to reduce the phenomenon of raised pitch, limiting any discord with the paired octave. This explanation also finds experimental confirmation. There are certainly still unresolved points; however, the experimental verification has made it possible to verify what is true and what is not.

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4) Juan Bermudo, *Declaration of Musical Instruments* (1555)*;* chapter LXXXV.
5) Vincenzo Galilei: *Dialogo di Vincentio Galilei nobile fiorentino della musica antica, et della moderna' in Fiorenza MDLXXXI*, (Florence: Giorgio Marescotti, 1581); p. 133.
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