TEATCUP LINERS: WHERE THE RUBBER MEETS THE TEAT

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A teatcup liner is defined in the ISO Terminology (1996) as "a flexible sleeve having a mouthpiece, a barrel and an integral or separate short milk tube". The origins of the two-chambered teatcup, incorporating a flexible sleeve or liner that is now used throughout the world, can be traced to the design of Hartnett and Robison of Balwyn, Victoria in 1893. Nevertheless, the credit for this invention is commonly attributed to another Australian, Alexander Gillies of Terang, Victoria in 1902.

Liners are made of natural, synthetic (usually nitrile) or silicone rubber. Liners of all designs must be shaped to:

1) provide an airtight seal at both ends of the shell;
2) provide a mouthpiece and barrel of a size which will fit on a range of teat shapes and sizes, minimizing liner slips and cluster fall-off;
3) milk out as quickly and completely as possible, minimizing teat congestion, discomfort, and injury;
4) clean easily.

Amongst the hundreds of commercially designs available throughout the world , the diameter of the mouthpiece lip ranges from 18-26 mm, the bore of the barrel from 18-30 mm, and the effective length from about 90-164 mm.

Common classifications for liners

Liners are commonly classified by their barrel size and shape, and by the material and/or method of their construction as follows.

1) *Size***.** Liners are commonly described as wide, medium or narrow-bore. A "wide-bore" liner usually has a bore greater than 24 mm (the diameter of a US 25 cent piece), and a "narrow-bore" liner has a bore size less than 21 mm (the diameter of a US nickel). In practice, it is more sensible to relate these classifications of "wide-bore" or "narrow-bore" to the average teat size for a given herd. In my view, a wide-bore liner has a bore (measured 75mm below the mouthpiece lip) that is > 1 mm larger than the mean teat diameter measured at the mid-point of the teats. A narrow-bore liner has a bore that is > 2mm smaller than the mean teat diameter. Note the minor discrepancy in the measurement points for the liner (75 mm from the top according to ISO) and for the teat (measured at the mid-point of the teat).

2) *Barrel shape.*

Longitudinal shape:	tapered or cylindrical sleeved or knobbed
Cross-section shape:	round, triangular, square, fluted, oval (pre-collapsed).

3) *Method of construction*.

1- or 2-piece (a 2-piece liner has a separate short milk tube).
Moulded or "stretch-bore" (a stretch-bore liner is a straight tube made of natural rubber with a rigid ring inserted to form the mouthpiece).

4) *Rubber type and composition*. (this affects longevity)

Natural rubber: good for 600-800 cow-milkings
Nitrile rubber or natural/nitrile blends: commonly 2500 cow-milkings in Australia because the carbon black content is typically about 25%; 1200 cow-milkings in USA (because the carbon black content must be less than 10%);
Silicone rubber: 3000-5000 cow-milkings, or 3-5 months, whichever comes sooner.

Liner Evaluation

Common acceptance tests for liner samples by manufacturers include:

1) Tension Set (or Permanent Set). This is the ratio of the permanent increase in length of a rubber sample, measured after elongation and release, compared with its original length. Tension set is affected by type of material and the processing conditions. Generally, only a relatively low tension set is acceptable, eg., 1.5-2.5% stretch after a constant force is applied for 90 min then removed for 10 min before measurement of the change in length.
2) Percent Swell after soaking in butteroil for 1-7 days.
3) Resistance to flexing
4) Puncture Resistance or Tear Strength.
5) Modulus, which is defined as the tensile stress required to produce a given elongation (for example 300%). Hardness and modulus of rubber compounds are closely related, both giving a measure of stiffness.

How can liners be categorized for the benefit of farmers and adviser? Currently, the best method has been to "suck it and see". Liner evaluation has been based primarily on measurement or observation of:

number of slips and falls per milking
milking time per cow
strip yields per cow
limited assessment of teat condition.

Newer techniques which can be used for quantifying liner performance include:

frequency distribution of strippings milk per quarter
more objective teat scoring
changes in teat thickness (measured just after compared with just before milking)
compressive load (or more correctly, cyclic liner pressure)
mouthpiece chamber vacuum
cow behaviour.

General effects of different liner characteristics

These notes should be interpreted with caution because it is often difficult to separate effects that are mutually inter-dependent.

Bore of the mid-barrel (usually measured 75 mm below the mouthpiece lip)
Other things being equal, increasing the internal diameter (the bore) of a liner causes:

- the liner to ride higher on any given teat
- higher strip yields, because the liner rides higher
- fewer teatcup slips and falls (except for tight-uddered, small-teated cows)
- more teat congestion and oedema.

A bore size of about 22 mm at the 75 mm measurement point allows most teat canals to open fully, assuming typical teat sizes for Australian herds.

Shape of the liner barrel
Some tapering of the barrel probably has an advantage in "fitting" a wider range of teat sizes and shapes. The shape of the liner "throat" has subtle but important effects on milking performance.

The cross-sectional shape has complex effects on the cyclic pressure applied by the closing liner to the teat. A circular cross-sectional shape is the simplest and most common but it may not necessarily be the optimum shape.

Length of the liner barrel
The liner needs to be long enough to collapse fully beneath the teat throughout milking. Therefore, longer teatcups have an advantage. If teatcups are too long, however, the cluster is more difficult to handle and the claw tends to drag on the floor under low-uddered cows. So how long is long enough? The effective length depends on the range of teat sizes in a herd, and on the liner bore. Wide-bore liners need greater effective length because the teat penetrates further into a wider bore liner. The minimum effective lengths of liners made from natural or synthetic rubber should be:

135 mm for liners with 21-22 mm bore at mid-barrel;
140 mm for liners of 23-24 mm bore;
145 mm for liners with a bore of 25 mm or more.

Ratio of mid-barrel bore to mouthpiece lip diameter
Other things being equal, increasing the barrel bore diameter with respect to the mouthpiece lip diameter causes:

- higher strip yields
- fewer teatcup slips and falls
- higher MP vacuum
- more congestion and oedema

Bore of upper barrel and height of liner mouthpiece chamber
Other things being equal, increasing the bore of the upper end of the liner barrel, or increasing

the height of the MP chamber (between the MP lip and the "throat" of the liner), causes:

- fewer teatcup slips and falls
- more teat congestion and oedema for smaller or shorter teats
- a higher proportion of reddened or bluish teats
- possibly more clinical infections according to recent Danish research.

Stiffness of liner mouthpiece lip

Other things being equal, increasing the stiffness of the liner MP lip causes:

- higher mouthpiece vacuum
- fewer teatcup slips and falls
- higher strip yields
- poorer cow behaviour (more kicking and stepping)

Wall thickness of the liner barrel

Other things being equal, increasing the wall thickness of the liner barrel causes:

- a higher pressure difference required to collapse the liner walls
- initially an increase in the cyclic pressure applied to a teat but, above about 2- 2.2mm, the applied pressure progressively declines (to zero at about 3.5mm wall thickness for a pressure difference of 40 kPa applied across the liner walls).

Liner mounting tension in its shell

Other things being equal, increasing the liner tension (by mounting the liner in a longer shell) causes:

- quicker milking, (partly because the liner opens faster, partly because of the higher cyclic pressure applied to the teat)
- more slips and falls (because the bore is reduced with respect to the MP lip diameter)
- poorer teat-end condition if the cyclic pressure applied by the liner is too high.

Bore of the short milk tube

Increasing the internal diameter of the short milk tube generally results in:

- slightly faster milking because there is less restriction to milk flow from teatcup to claw;
- less likelihood of “impacts” (that is, droplets or slugs of milk propelled up the short milk tube towards the teat end) because the cyclic liner vacuum is more stable;
- higher transient air flow into the milking system while teatcups are being attached to the teats, or when liners slip, cups fall or a cluster is kicked off.