# CHAPTER 4
# RESULTS AND DISCUSSION

## 4.1 Examination of Herbal Powders

The examination of herbal characteristics using macroscopic and microscopic methods in confirming types of medicinal plants revealed that all herbs used in this research were accurate and compatible with what presented in Thai Herbal Pharmacopoeia (Vichiara et al., 1995 & 2000) or Standard of Asean Herbal Medicine (ASEAN countries, 1993). The results of the sudy from this phase were shown in Fig 4.1-4.23. Regarding herb quality examination processed by measuring the total ash and the acid insoluble ash, it was found that all measured values are in accordance with the standard (Table 4.1).

### 4.1.1 Macroscopic characteristics

The macroscopic characteristics of herbal specimens classified by part used, namely fruit, underground part, leaf and stem were shown in Fig. 4.1-4.4.

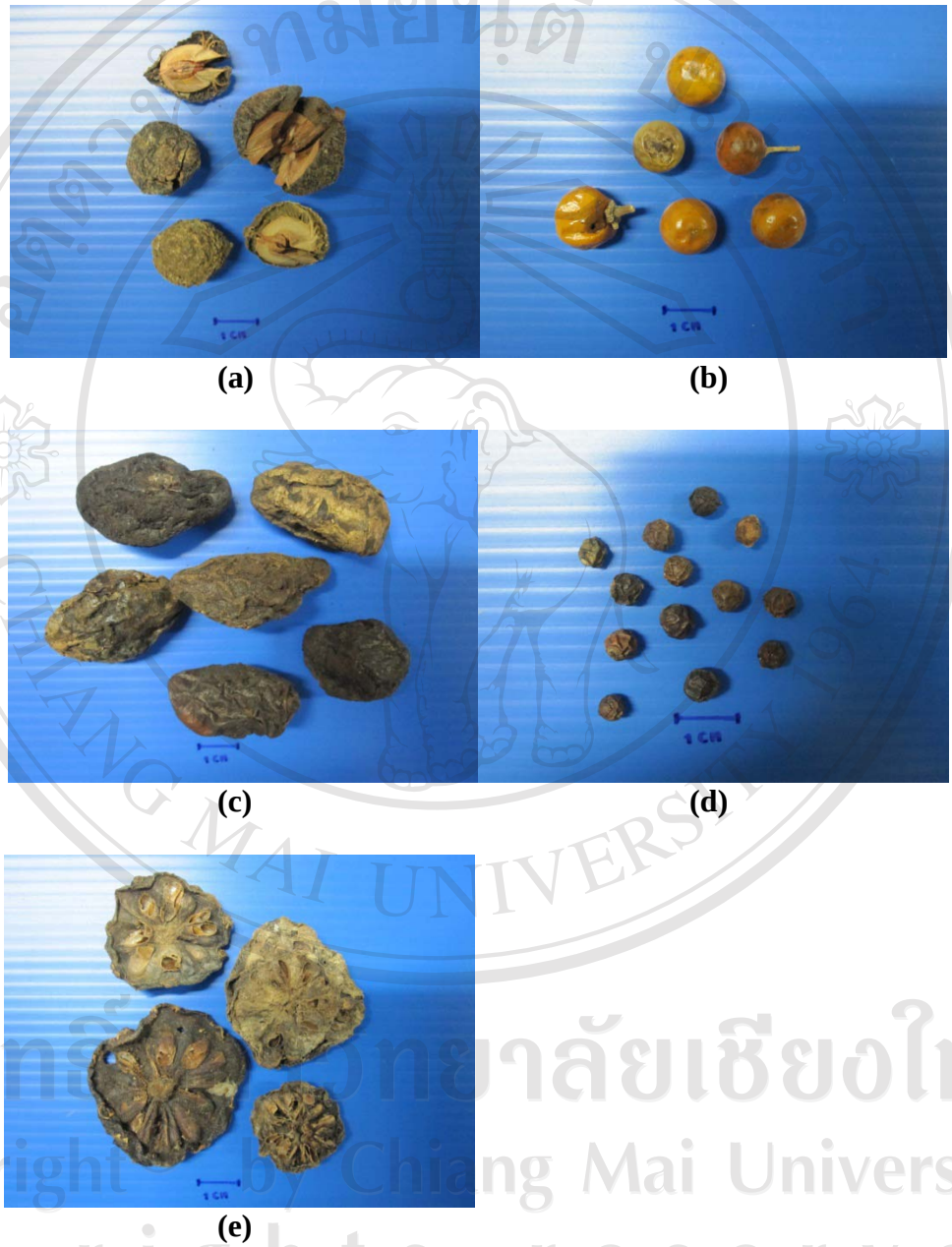
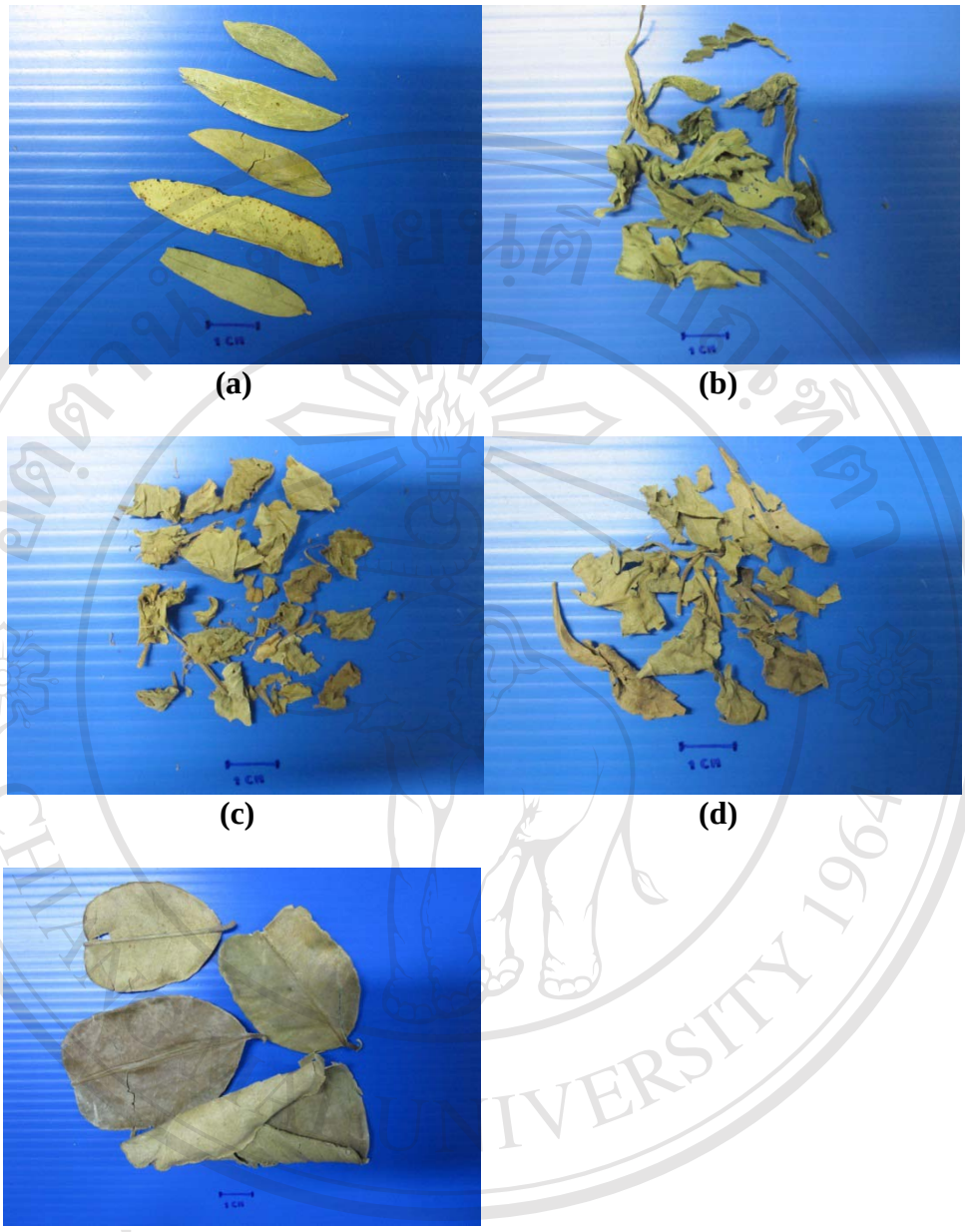



**Fig 4.1** Macroscopic characteristics of crude drugs from herbal fruit
(a) *P. emblica* (b) *S. trilobatum* (c) *T. chebula* (d) *P. nigrum* and
(e) *M. citrifolia*

**Fig 4.2** Macroscopic characteristics of crude drugs from herbal underground part (a) *Z. officinale* (b) *C. longa* (c) *A. calamus* (d) *E. longifolia* and (e) *G. glabra*

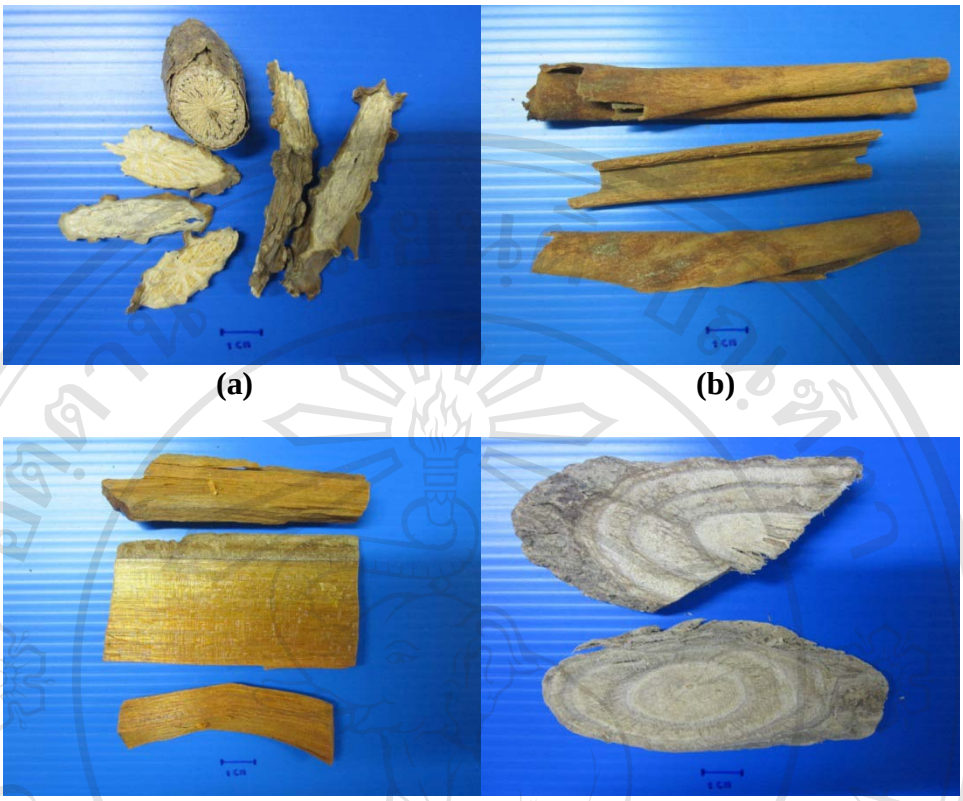


**(a)** **(b)**

**(c)** **(d)**

**(e)**

**Fig 4.3** Macroscopic characteristics of crude drugs from herbal leaf (a) *C. angustifolia* (b) *A. paniculata* (c) *C. asiatica* (d) *P. indica* and (e) *C. hystrix*



**(a)** **(b)**

**(c)** **(d)**

**Fig 4.4** Macroscopic characteristics of crude drugs from herbal stem
(a) *T. crispa* (b) *C. verum* (c) *C. sappan* and (d) *D. scandens*

Investigation of herbal macroscopic characteristics showed that the morphology of herbal specimens used in the study was in agreement with those defined in the referenced documents (Vichiara et al., 1995 & 2000; Faculty of pharmacy, Mahidol university, 1986; Norman et al.1992)

### 4.1.2 Microscopic characteristics

The microscopic characteristic of herbal powder were shown in Fig 4.5-4.23

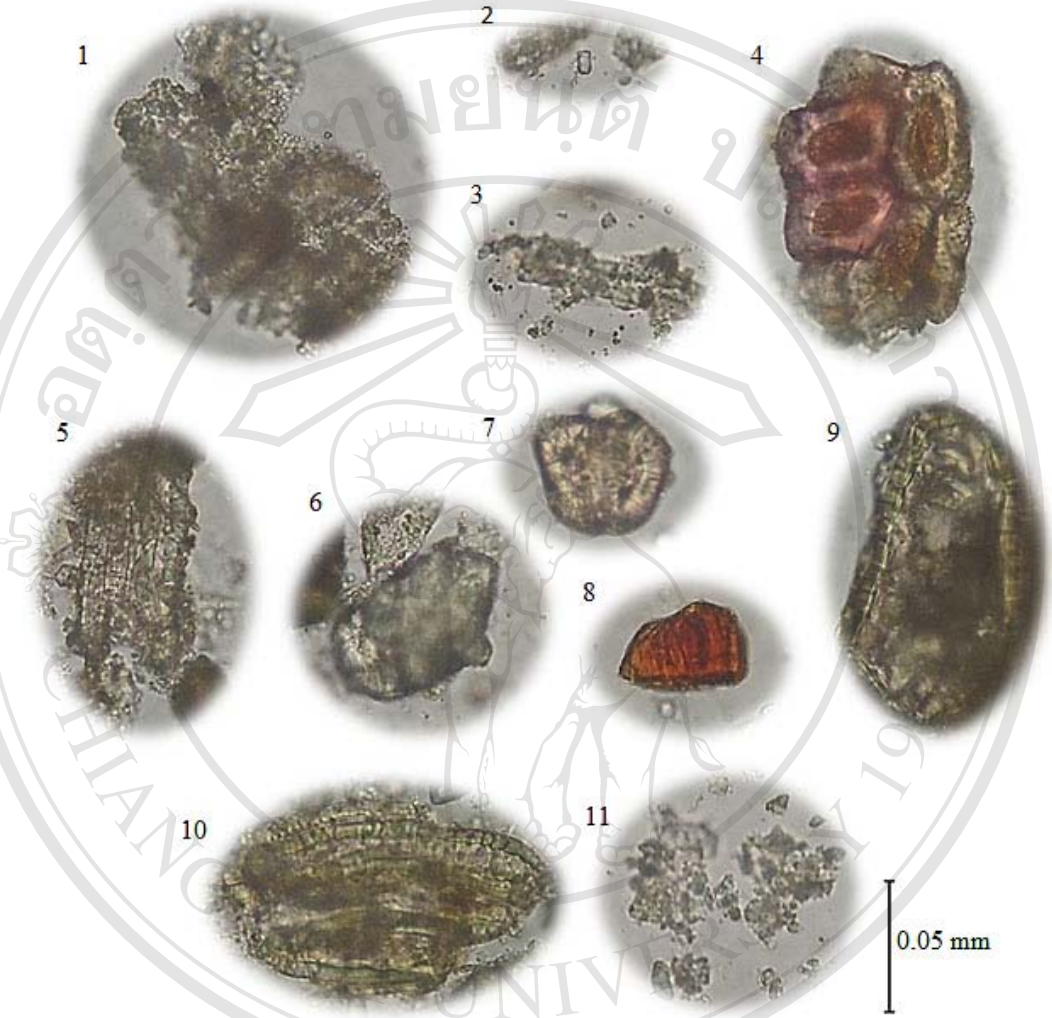



**Fig 4.5** Powdered drug of the pericarp of ***P. emblica***

1. Epicarp in surface view
2. Prismatic crystals
3. Fibrous sclereids
4. Thick-walled parenchyma containing reddish masses
5. Fibrous sclereids from seed coat
6. Grey masses
7. Sclereids
8. Reddish masses
9. Sclereids containing grey masses
10. Sclerenchyma sclereids from seed coat
11. Tannin granules


**Fig 4.6** Powdered drug of the fruit of ***S. trilobatum***

1. Epidermis of pericarp in surface view
2. Thick walled parenchyma of pericarp
3. Sclerenchymatous layer of testa in surface view
4. Sclerenchymatous layer of testa in surface view from below
5. Endosperm with oil droplets
6. Embryo with oil droplets

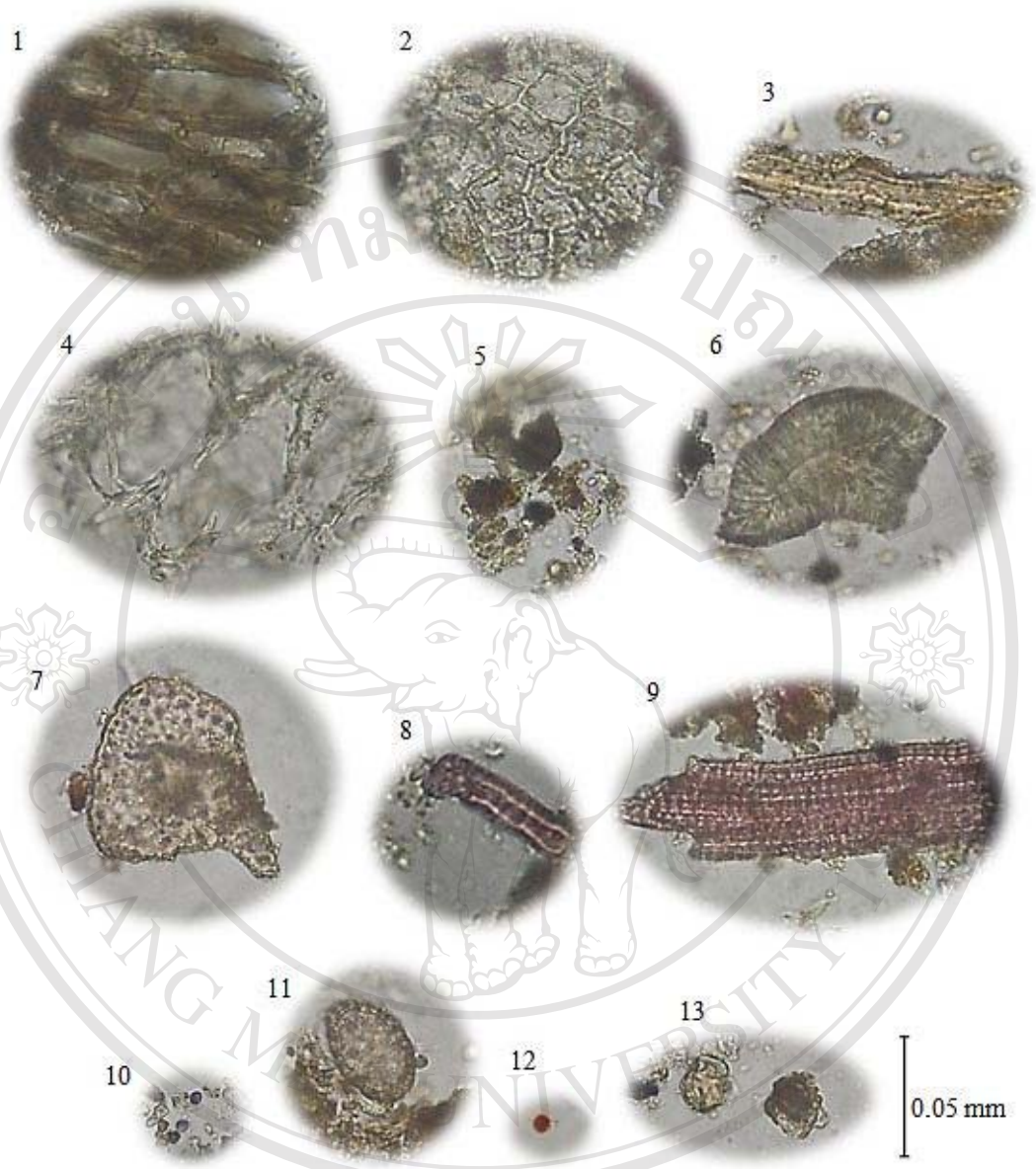



**Fig 4.7** Powdered drug of the fruit of ***T. chebula***

1. Epidermis in sectional view
2. Epidermis in surface view
3. Fiber and starch grains
4. Ground parenchyma
5. Masses of brownish black material
6. Sclerenchyma of endocarp
7. Porous parenchyma
8. Sclereid
9. Vessels stain with solution of phloroglucinol in 20 % HCl
10. Starch grains
11. Reticulate parenchyma
12. Oil globule stain with Sudan III solution
13. Parenchyma containing rosette aggregate crystal

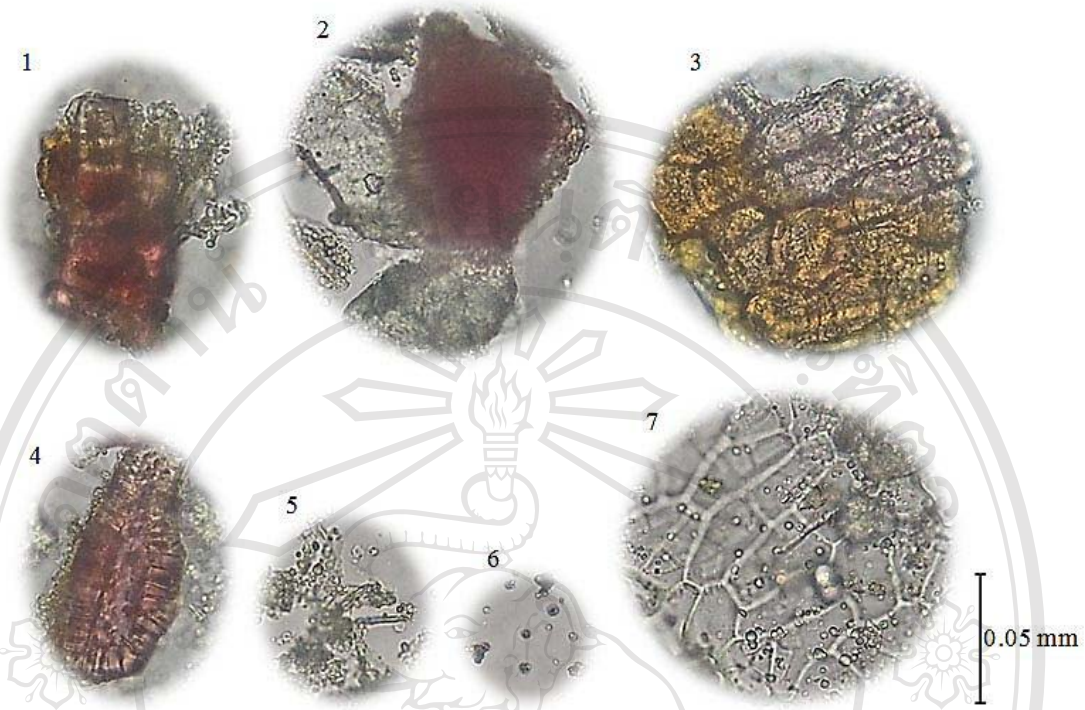



**Fig 4.8** Powdered drug of the fruit of ***P. nigrum***

1. Stone cells
2. Perisperm tissue with starch granules and resin
3. Epidermal cells of epicarp
4. Typical stone cell stain with solution of phloroglucinol in 20 % HCl
5. Crystals of piperine
6. Starch granules
7. Polygonal cells of mesocarp

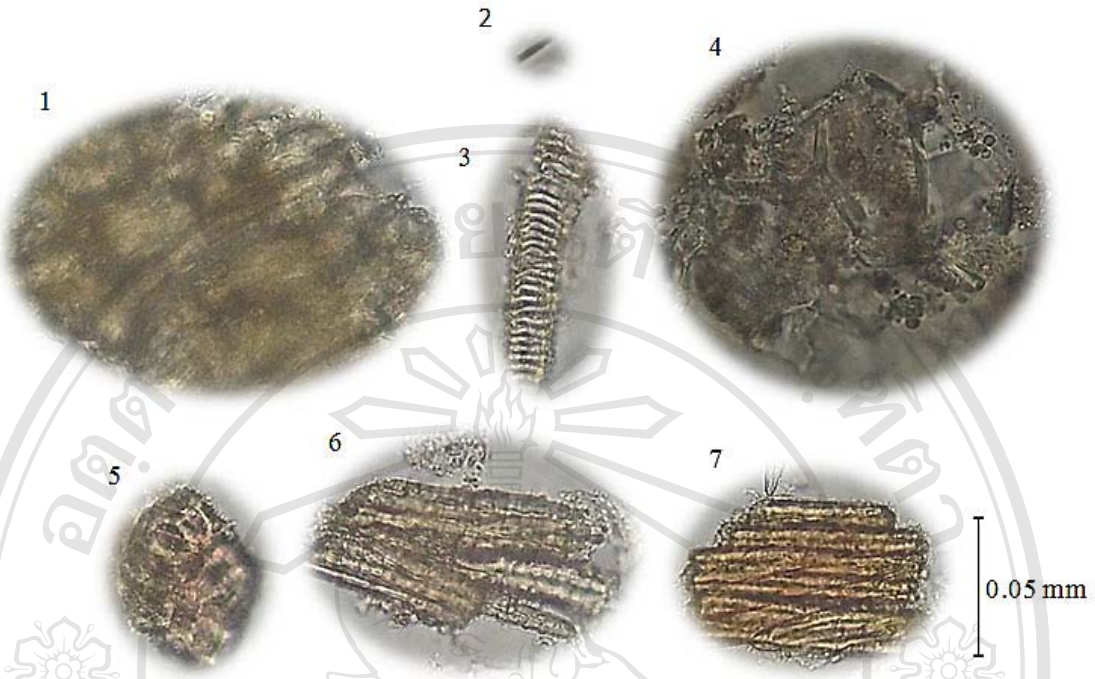



**Fig 4.9** Powdered drug of the fruit of ***M. citrifolia***

1. Parenchyma of mesocarp
2. Acicular crystal of calcium oxalate
3. Part of vessel
4. Sclereids associated with parenchyma
5. Sclereids
6. Tracheae
7. Parenchyma of spermoderm in surface view

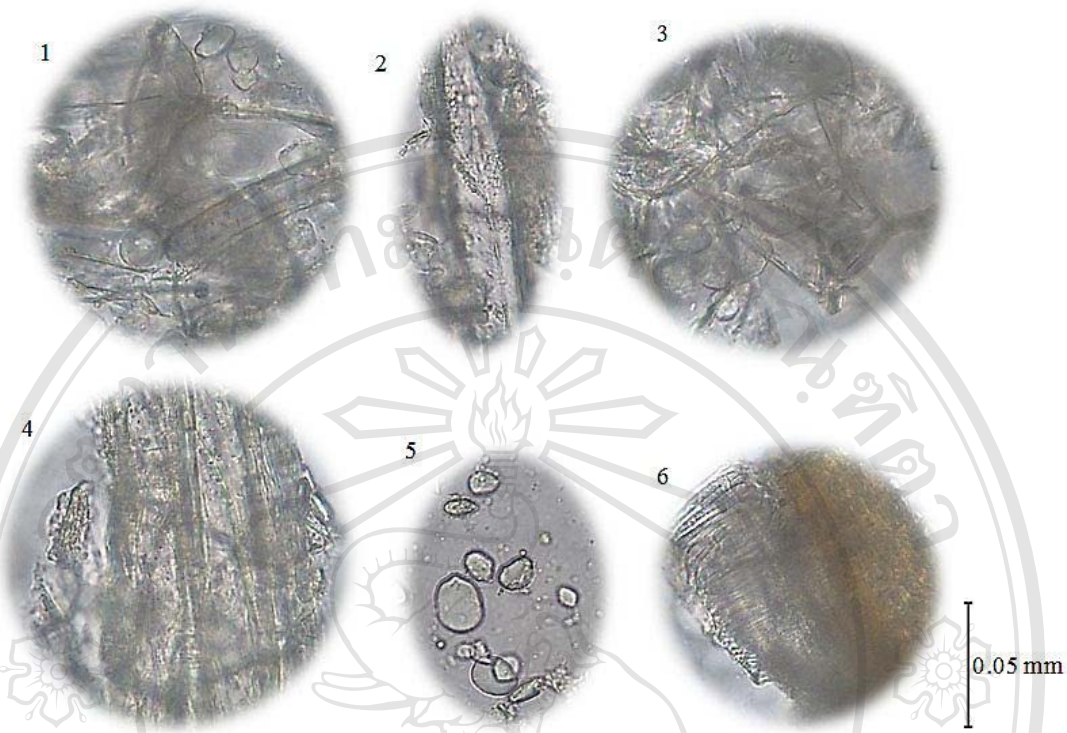



**Fig 4.10** Powdered drug of the rhizome of ***Z. officinale***

1. Parenchymatous cells with adherent starch granules
2. Part of fiber
3. Cork in surface view underlying with parenchymatous cells containing starch granules
4. Parts of fibers with dentate walls, showing septa
5. Starch granules
6. Parts of reticulate vessel with associated pigment cell

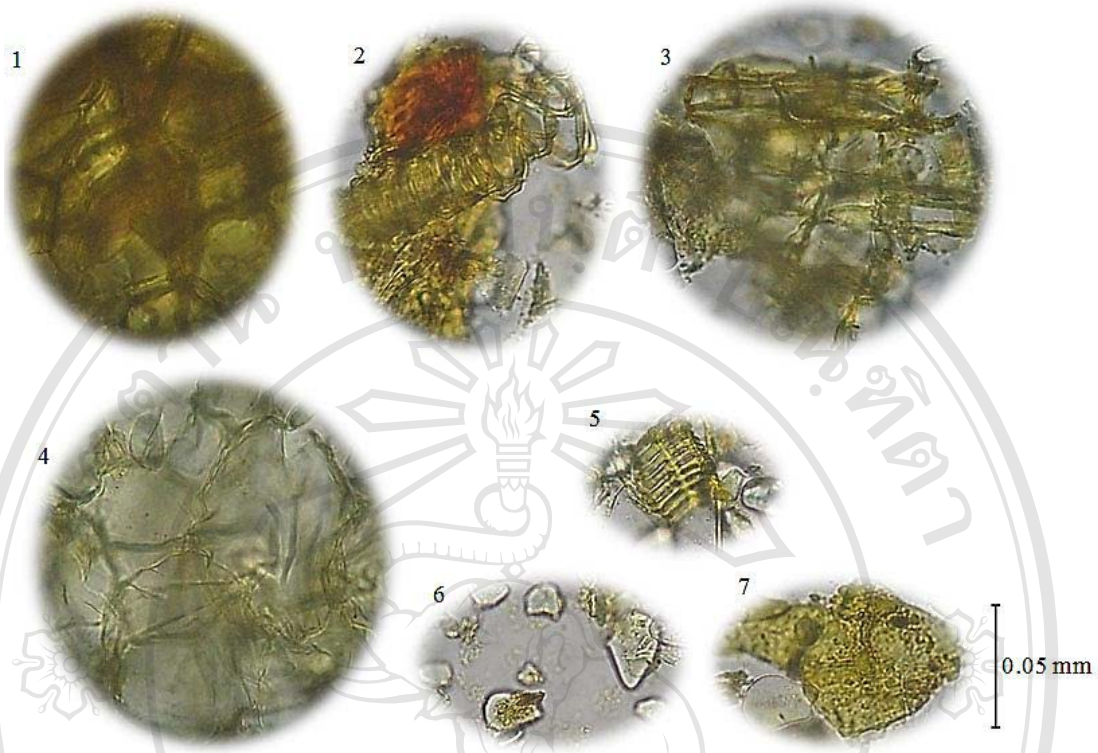



**Fig 4.11** Powdered drug of the rhizome of ***C. longa***

1. Cork in surface view
2. Spirally thickened vessel
3. Outer tissue in sectional view showing epidermis and cortex
4. Parenchymatous cell
5. Reticulately thickened vessel
6. Starch granules
7. Parenchymatous cell filled gelatinised starch and yellow matter

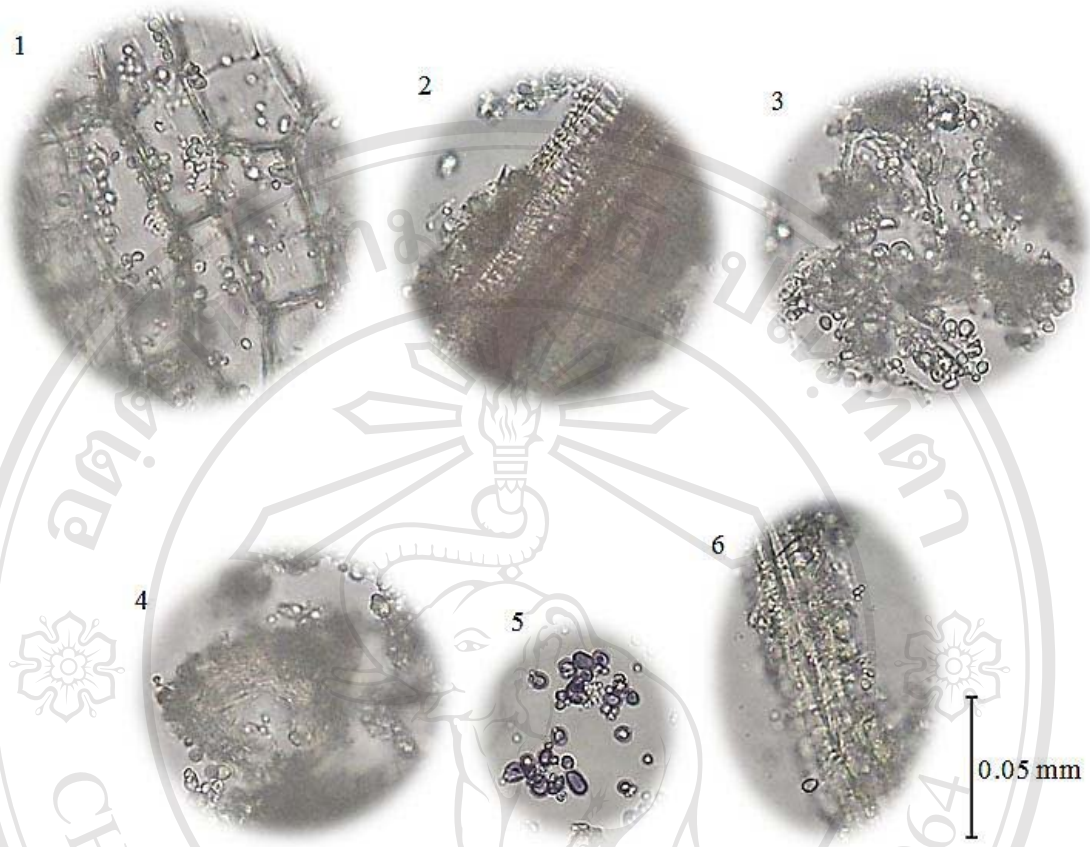



**Fig 4.12** Powdered drug of the rhizome of ***A. calamus***

1. Epidermis
2. Vessels
3. Fragment of parenchymatous cells in sectional view
4. Large oil cell
5. Starch granules stain with Iodine solution
6. Fibers with calcium oxalate prism sheath

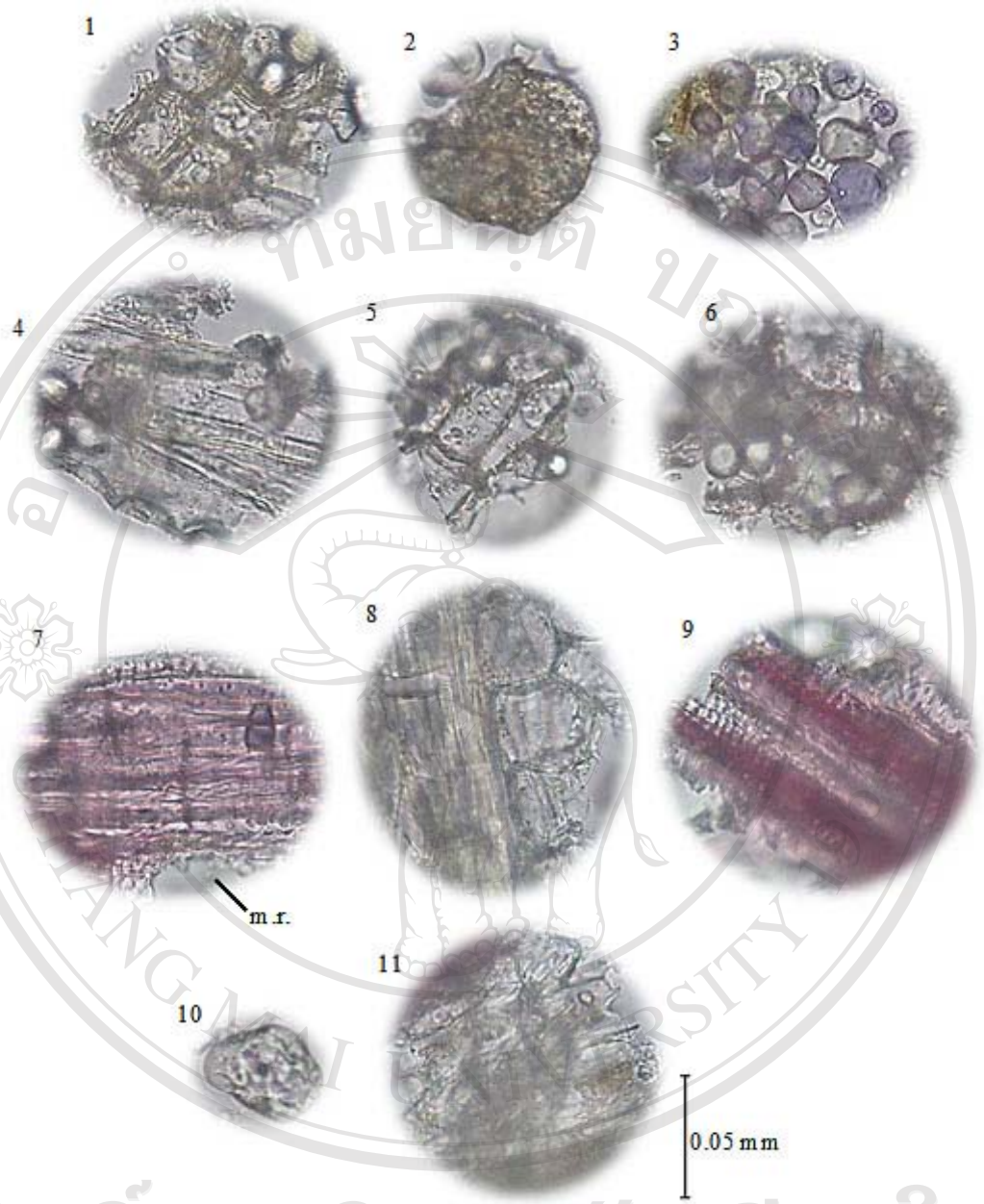



**Fig 4.13** Powdered drug of the root of ***E. longifolia***

1. Cork in surface view
2. Mass of brownish pigments
3. Starch granules stain with Iodine solution
4. Fragment of fibers
5. Xylem parenchyma in longitudinal view
6. Xylem parenchyma in sectional view with starch granules
7. Xylem fibers and part of a medullary ray stain with solution of phloroglucinol in 20% HCl in radial-longitudinal view
8. Xylem fibers and part of a medullary ray in tangential-longitudinal view
9. Fragment of large bordered pitted vessels stain with solution of phloroglucinol in 20% HCl
10. Stone cell
11. Fragment of parenchyma cells from the cortex

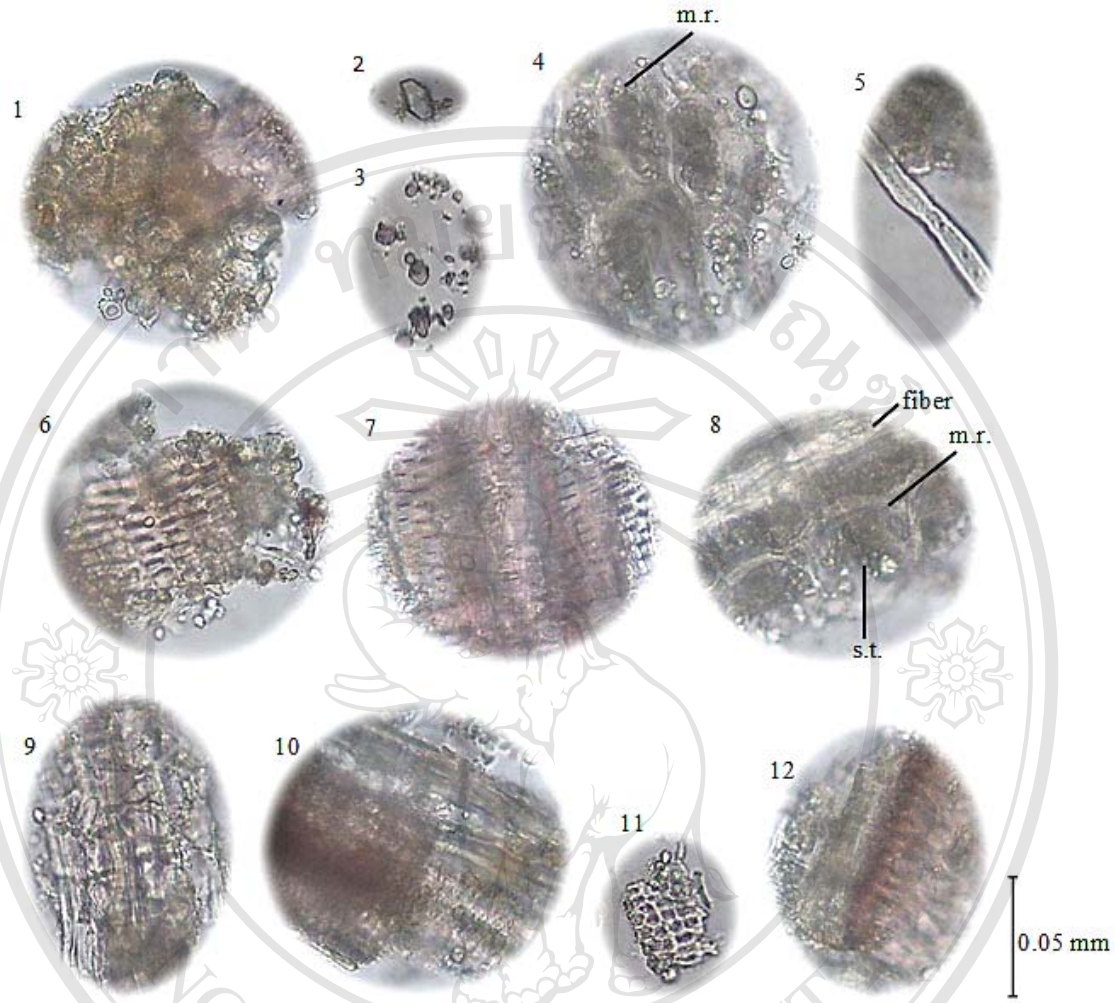



**Fig 4.14** Powdered drug of the root of ***G. glabra***

1. Cork in surface view
2. Prism of calcium oxalate
3. Starch granules
4. Part of a medullary ray (m.r.) containing starch granules
5. Part of a single fiber
6. Fragment of a large vessel with elongated pits
7. Part of a group of smaller vessels with bordered pits
8. Part of medullary ray (m.r.) containing starch granules (s.t.) in tangential longitudinal section with part of fiber
9. Part of a group of fibers with incomplete calcium oxalate prism sheath
10. Lignified xylem parenchyma with part of underlying bordered pitted vessel
11. Fragment of a bordered pitted vessel
12. Part of a medullary ray in radial longitudinal section with part of a bordered pitted vessel

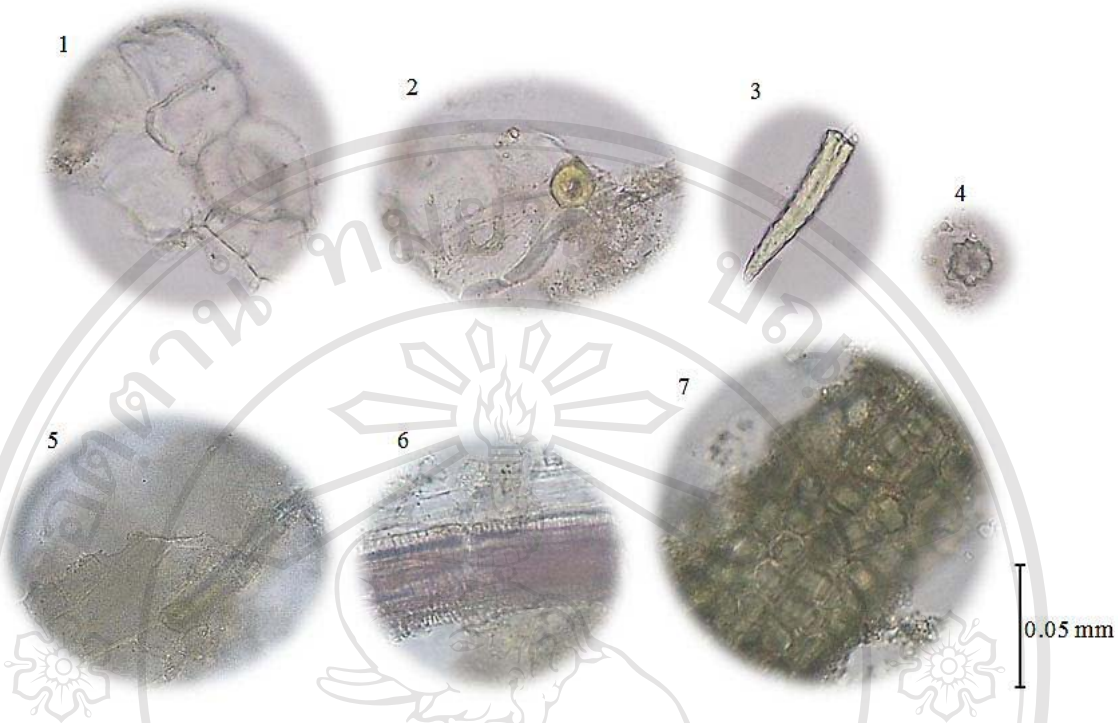



**Fig 4.15** Powdered drug of the leaf of ***C. angustifolia***

1. Epidermis in surface view showing paracytic stomata and underlying palisade cells
2. Epidermis in surface view showing cicatrix and underlying palisade cells
3. Fragment of covering trichome
4. Rosette crystal of calcium oxalate
5. Epidermis in surface view with attached trichome
6. Xylem element from one of the larger veins stain with solution of phloroglucinol in 20 % HCl
7. Group of fibers with calcium oxalate prism sheaths

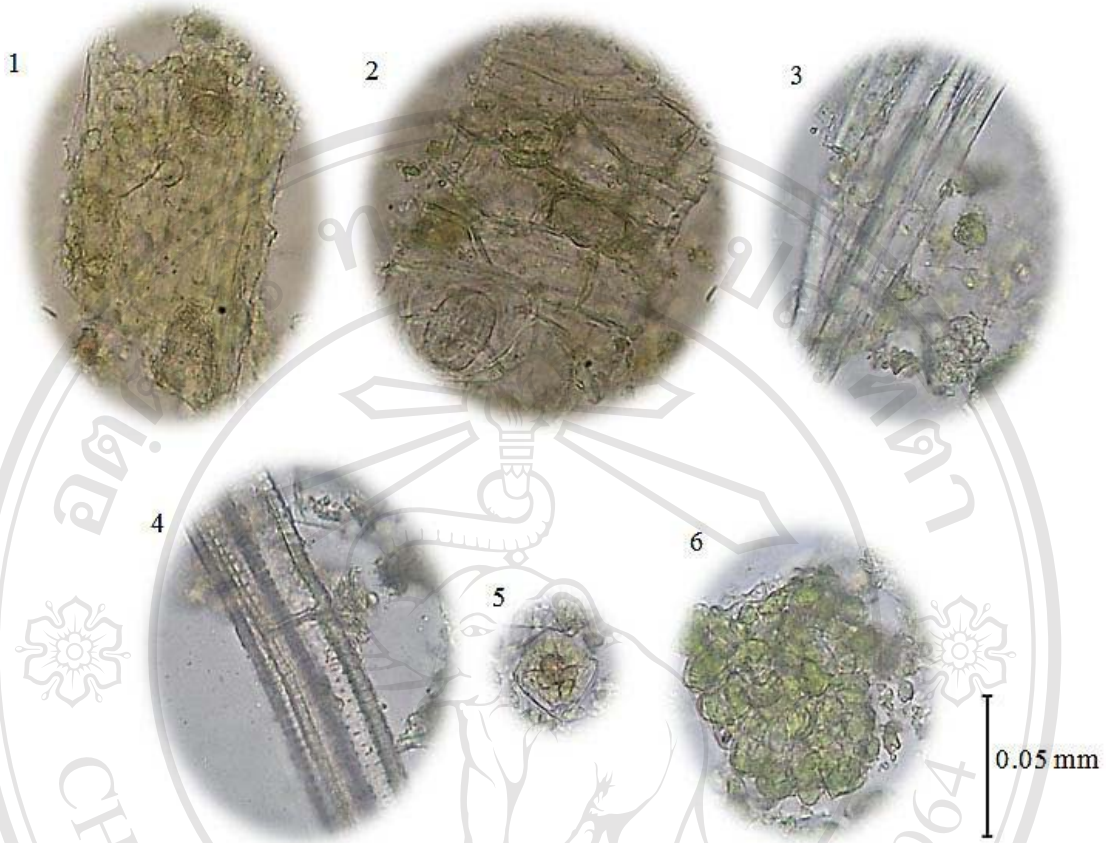



**Fig 4.16** Powdered drug of the leaf of ***A. paniculata***

1. Lower epidermis of the leaf in surface view showing diacytic stomata, lithocyst cells and glandular trichome.
2. Elongated epidermis with lithocyst cells and stomata
3. Fragment of fibers
4. Fragment of xylem tissues, showing xylem parenchyma and vessels
5. Glandular trichome
6. Epidermis at the edge of the leaf with mesophyll in surface view

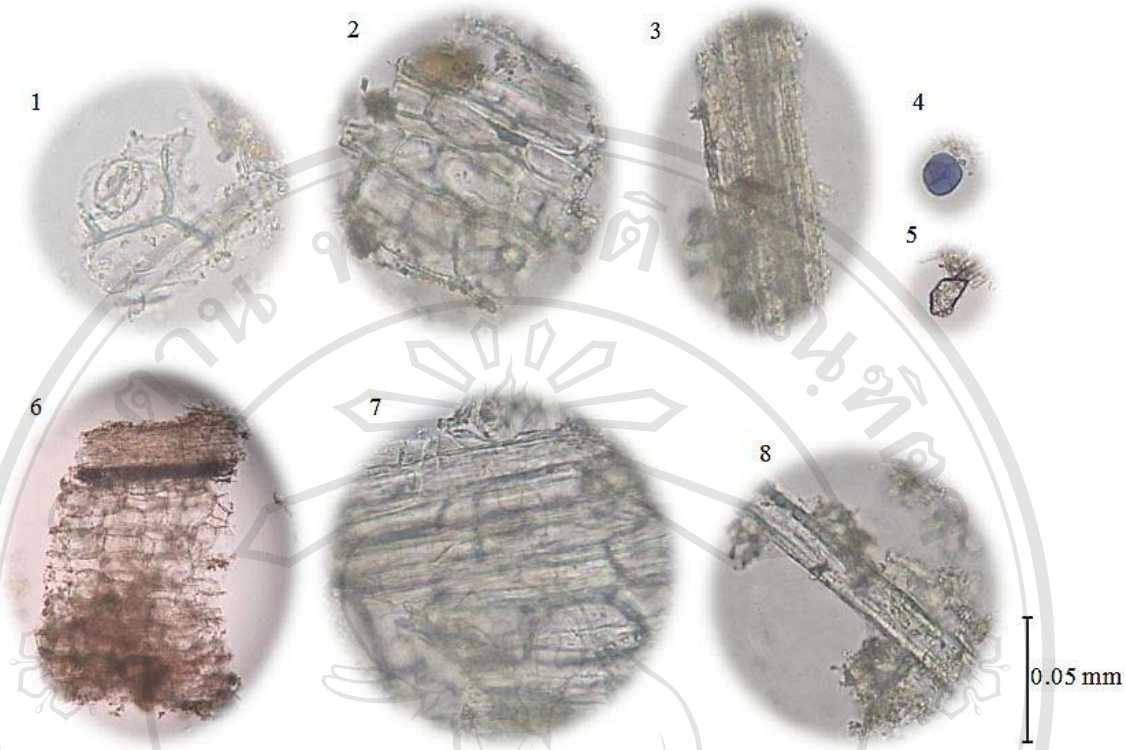



**Fig 4.17** Powdered drug of the leaf of ***C. asiatica***

1. Lower epidermis in surface view with anisocytic stomata
2. Part of the lamina in sectional view with rosette aggregates crystals
3. Part of stolon in longitudinal view showing vessels, fiber and parenchyma cells
4. Starch granule stain with Iodine solution
5. Prism of calcium oxalate
6. Part of stolon in surface view showing epidermal cells and cuticular striation
7. Epidermal cells
8. Part of lignified fiber

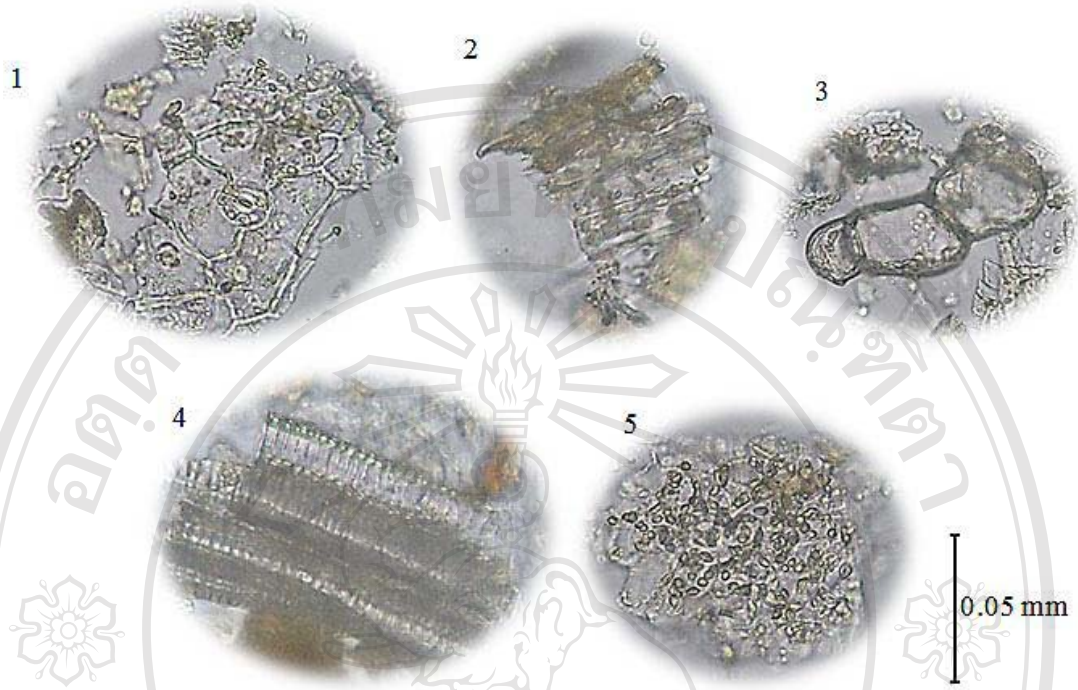



**Fig 4.18** Powdered drug of the leaf of ***P. indica***

1. Epidermis in surface view showing anomocytic stoma
2. Lamina in sectional view
3. Glandular hair
4. Part of a vascular bundle
5. Lamina in surface view showing the underlying mesophyll

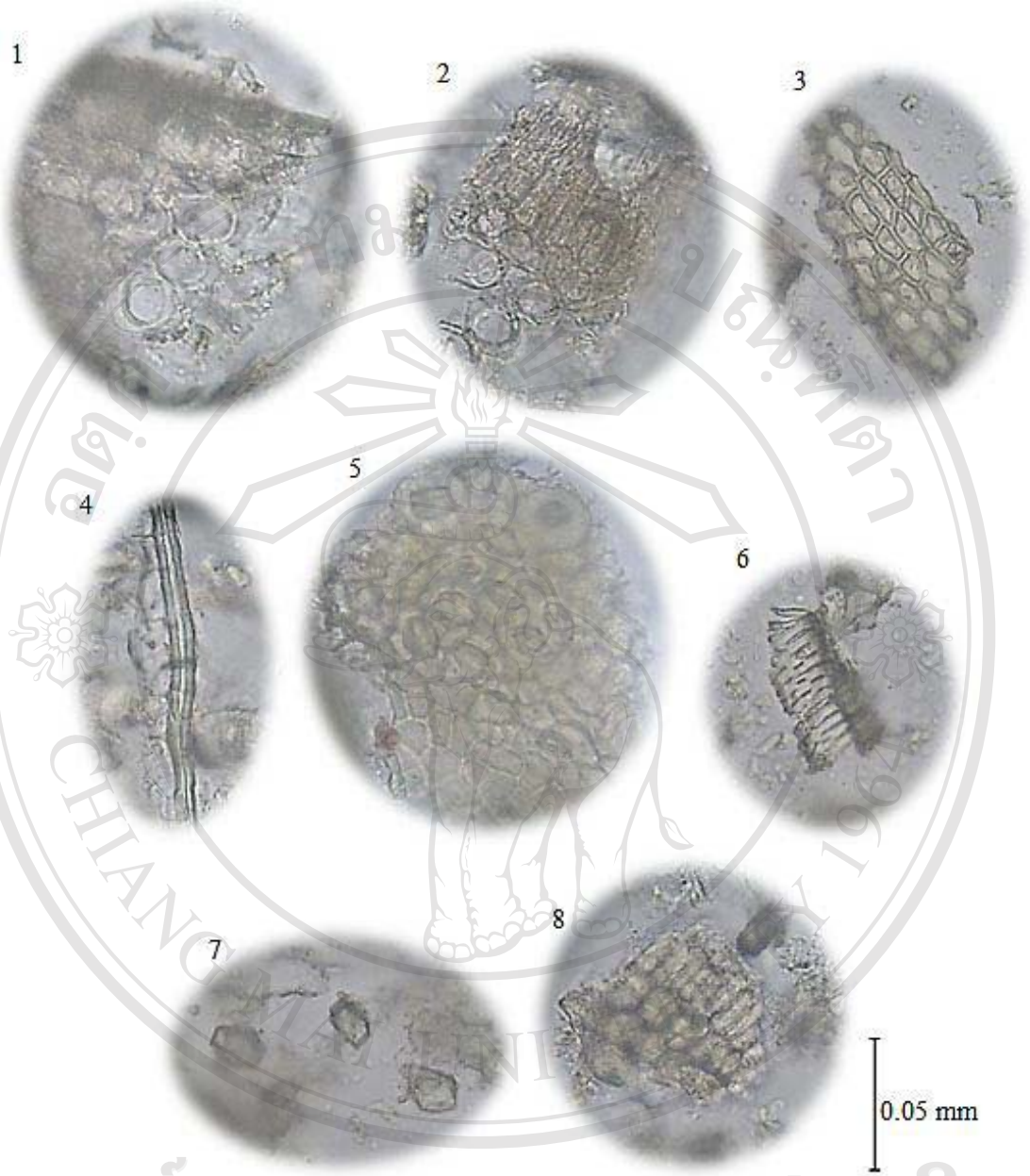



**Fig 4.19** Powdered drug of the leaf of ***C. hystrix***

1. Epidermis and collenchyma in sectional view
2. Lamina in sectional view
3. Upper epidermis in surface view
4. Fibers
5. Lower epidermis in surface view showing stomata and the underlying idioblasts containing prismatic crystals of calcium oxalate
6. Vessel
7. Prismatic crystals of calcium oxalate
8. Epidermis of midrib in surface view

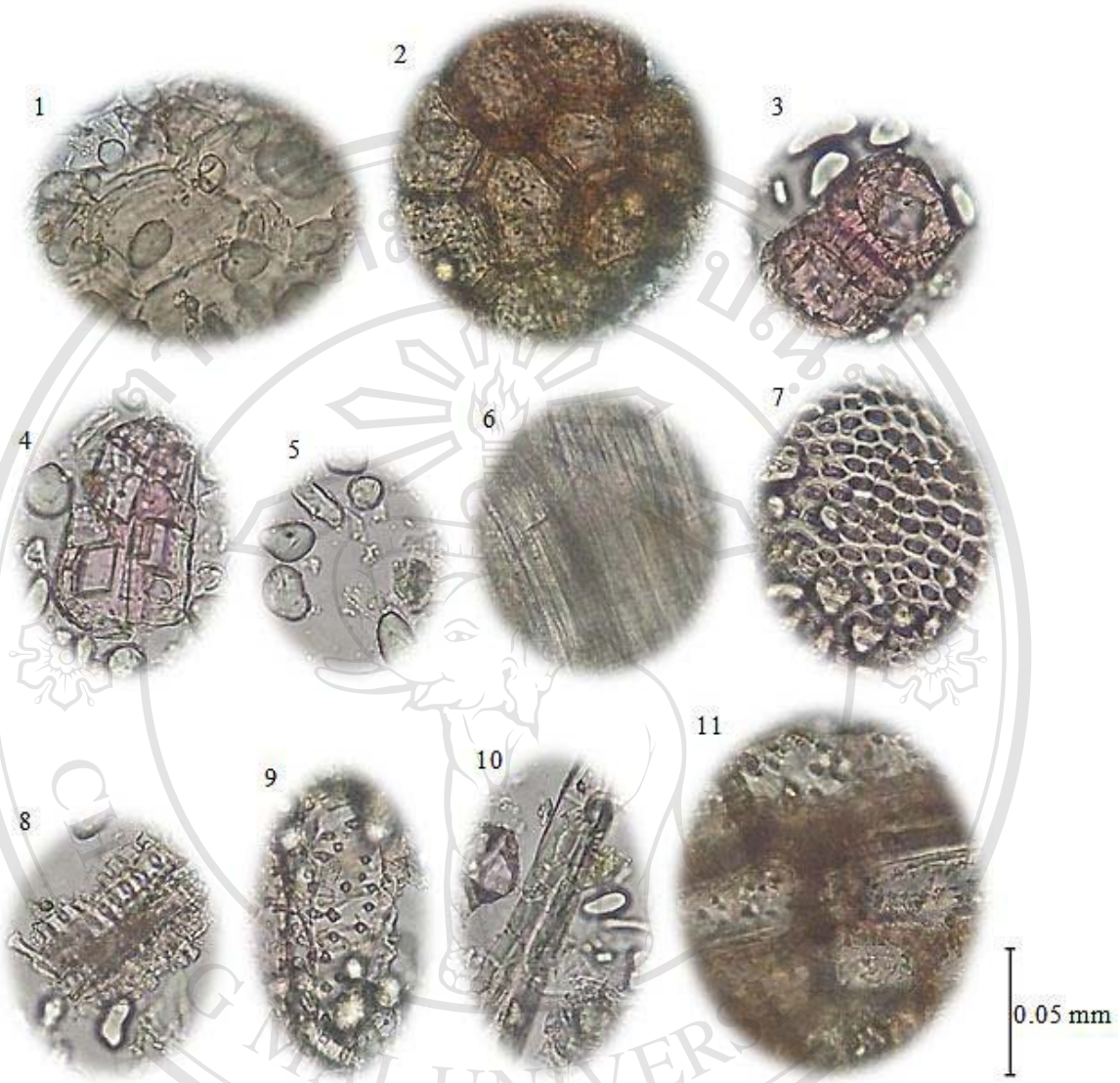



**Fig 4.20** Powdered drug of the stem of ***T. crispa***

1. Cortical parenchyma
2. Cork in surface view
3. Stone cells stain with solution of phloroglucinol in 20 % HCl
4. Parenchyma cells with prismatic crystals
5. Starch granules
6. Phloem cells
7. Bordered pitted vessels
8. Reticulate vessel
9. Pitted vessel
10. Fragments of bast fibers with dentated wall
11. Xylem parenchyma with lignified wall

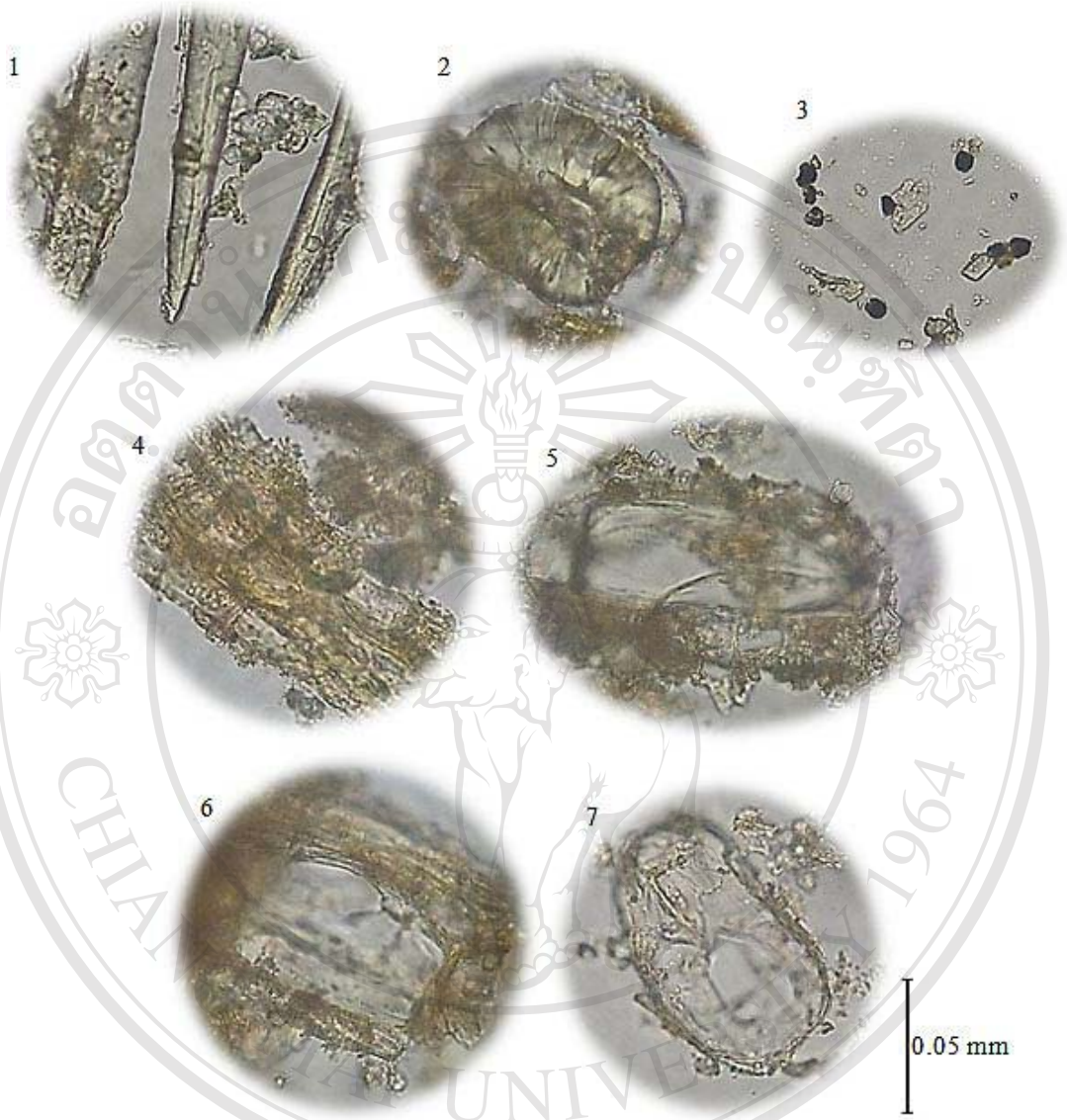



**Fig 4.21** Powdered drug of the stem bark of ***C. verum***

1. Fibers
2. Sclereid
3. Starch granules stain with Iodine solution and calcium oxalate crystals
4. Cork in surface view
5. Phloem parenchyma and oil cell
6. Part of a fiber with an associated oil cell
7. A single oil cell

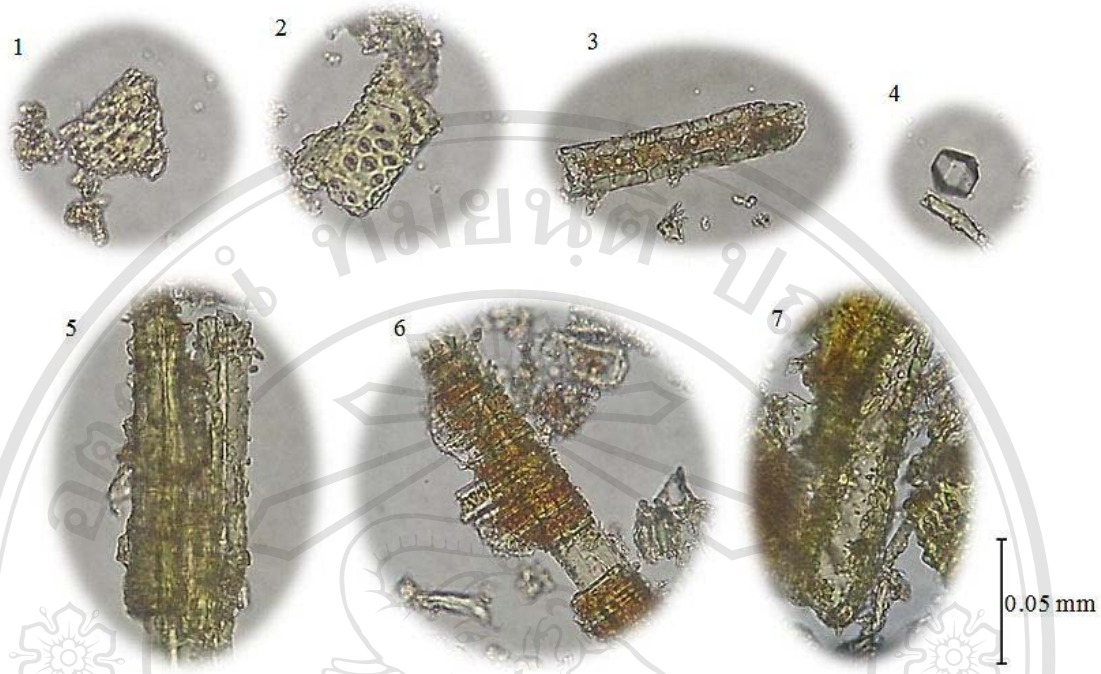



**Fig 4.22** Powdered drug of the stem of ***C. sappan***

1. Fragment of reticulated vessel
2. Fragment of bordered pitted vessel
3. Medullary ray containing starch granules
4. Prismatic crystal of calcium oxalate
5. Wood fibers
6. Part of a group of wood fiber with overlying medullary ray
7. Wood parenchyma

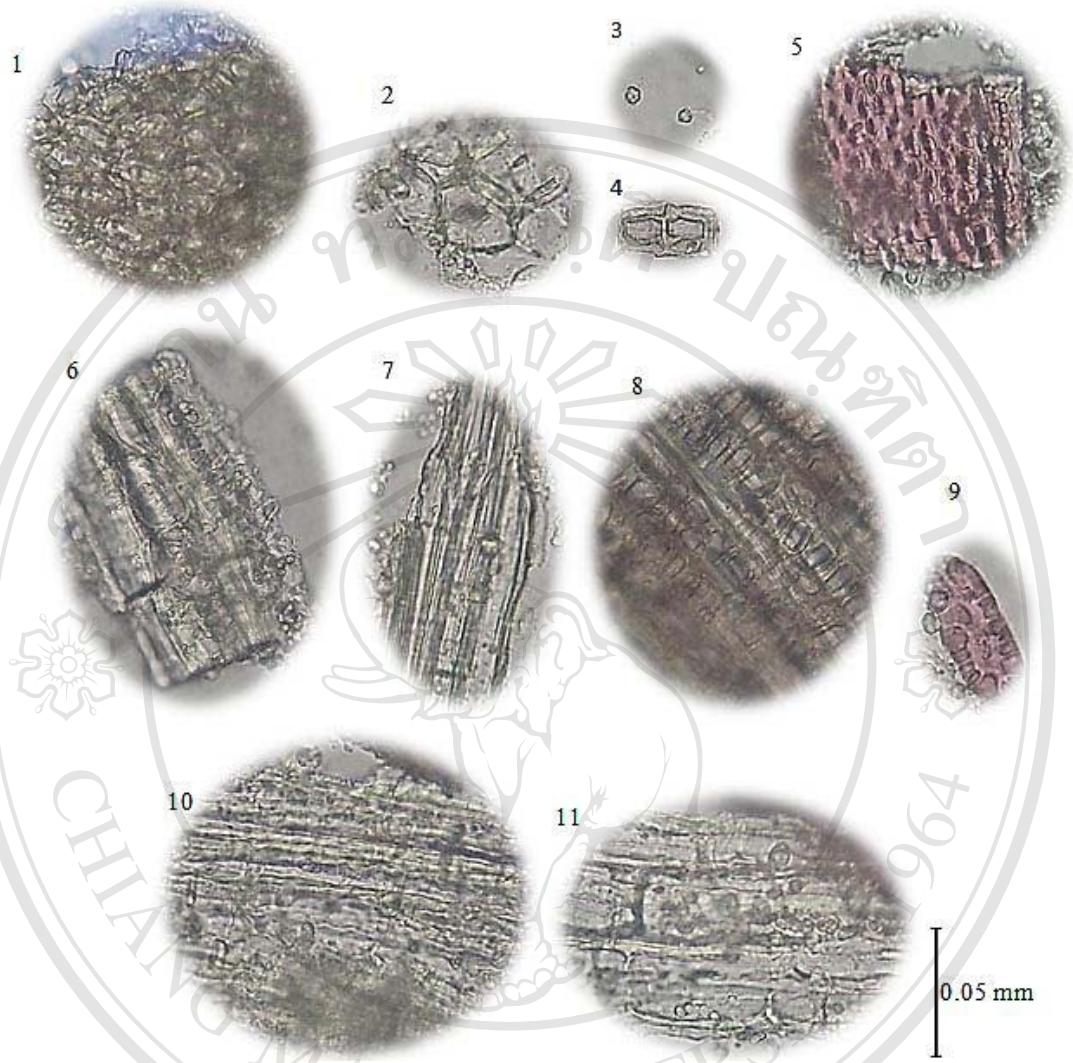



**Fig 4.23** Powdered drug of the stem of ***D. scandens***

1. Cork in surface view
2. Parenchymatous cells containing starch granules
3. Starch granules
4. Prisms of calcium oxalate in parenchyma cells
5. Fragment of bordered pitted vessels stain with solution of phloroglucinol in 20 % HCl
6. Part of medullary ray with underlying xylem parenchyma
7. Group of fibers with underlying medullary ray
8. Group of fibers with part of calcium oxalate prism sheath
9. Sclereid stain with solution of phloroglucinol in 20 % HCl
10. Part of medullary ray showing xylem parenchyma with underlying xylem fibers
11. Fragment of xylem parenchyma

Investigation of herbal microscopic characteristics showed that the histology of herbal specimens used in the study was in agreement with those defined in the referenced documents (Vichiara et al., 1995 & 2000; Faculty of pharmacy, Mahidol university, 1986; Norman et al.1992).

**4.2 Herbal Powder Composition**

The herbal powder composition in each part of plants was quite different. Fiber was found at higher contents in stem and fruit than in leaf and underground part. The highest fiber content was found in *C. sappan* (55.03±0.05%), *T. chebula* (31.17±0.17%), *S. trilobatum* (30.28±0.23%) and *D. scandens* (30.17±0.12%), respectively (Table 4.1). The reason for this finding may be that both parts of plants need more strength than other parts do.

More starch content was found in underground part of plants than in other parts. The highest amount was found in *A. calamus* (44.45±0.34%), *E. longifolia* (39.39±0.69%), *Z. officinale* (32.75±0.65%) and *C. longa* (31.38±0.15%), respectively (Table 4.1). It could be considered that underground part is the part in which plants accumulate food in a form of starch granules.

Volatile oil was found in six plants including *P. nigrum* (1.43±0.21%), *Z. officinale* (1.53±0.12%), *C. longa* (6.83±0.29%), *A. calamus* (2.80±0.40%), *C. hystrix* (0.93±0.12%) and *C. verum* (0.82±0.03%)(Table 4.1). Volatile oil is a secondary metabolite. It is a composition which is produced by a certain plant species and can be found in every part of the plants.

**Table 4.1** Quantitative analysis and basic composition of herbal powder

| Sample Type | Total Ash % (w/w) | | Acid Insoluble Ash %(w/w) | | Volatile Oil Content %(v/w) | | Fiber Content %(w/w) | Starch Content %(w/w) | Moisture Content %(w/w) |
|---|---|---|---|---|---|---|---|---|---|
| | Standard | Experimental | Standard | Experimental | Standard | Experimental | | | |
| **Fruit** | | | | | | | | | |
| *P. emblica* | 4.0 | 4.43±0.11 | 1.0 | 0.51±0.09 | ND | ND | 18.77±0.21 | ND | 5.56±0.09 |
| *S. trilobatum* | - | 12.21±0.02 | 1.0 | 0.64±0.06 | ND | ND | 30.28±0.23 | 0.86±0.01 | 6.08±0.03 |
| *T. chebula* | 6.5 | 6.72±0.04 | 1.0 | 1.05±1.49 | ND | ND | 31.17±0.17 | 1.17±0.26 | 5.66±0.02 |
| *P. nigrum* | 7.0 | 4.00±0.07 | 1.5 | 0.17±0.03 | ≥ 1.0 | 1.43±0.21 | 10.52±0.06 | 36.48±1.41 | 6.70±0.05 |
| *M. citrifolia* | 7.0 | 7.10±0.28 | 2.0 | 1.98±1.51 | ND | ND | 21.14±0.11 | 3.08±0.38 | 6.71±0.15 |
| **Underground part** | | | | | | | | | |
| *Z. officinale* | 8.0 | 8.14±0.56 | 1.8 | 0.88±0.63 | 2.0 | 1.53±0.12 | 7.97±0.13 | 32.75±0.65 | 6.78±0.51 |
| *C. longa* | 8.0 | 9.10±0.42 | 1.0 | 0.90±0.06 | ≥ 6.0 | 6.83±0.29 | 5.80±0.05 | 31.38±0.15 | 6.63±0.01 |
| *A. calamus* | 7.0 | 3.64±0.40 | 2.0 | ND | ≥ 1.2 | 2.80±0.40 | 7.95±0.06 | 44.45±0.34 | 7.37±0.03 |
| *E. longifolia* | 4.0 | 3.74±0.05 | 1.0 | 1.06±0.06 | ND | ND | 21.12±0.22 | 39.39±0.69 | 6.14±0.04 |
| *G. glabra* | 10.8 | 5.90±0.04 | 4.0 | 0.81±0.16 | ND | ND | 12.08±0.22 | 16.48±0.10 | 7.14±0.06 |

**Table 4.1** Quantitative analysis and basic composition of herbal powder (cont.)

| Sample Type | Total Ash % (w/w) | | Acid Insoluble Ash %(w/w) | | Volatile Oil Content %(v/w) | | Fiber Content %(w/w) | Starch Content %(w/w) | Moisture Content %(w/w) |
|---|---|---|---|---|---|---|---|---|---|
| | Standard | Experimental | Standard | Experimental | Standard | Experimental | | | |
| **Leaf** | | | | | | | | | |
| *C. angustifolia* | 16.0 | 11.57±0.04 | 4.0 | 0.86±0.39 | ND | ND | 8.19±0.29 | 5.06±0.29 | 7.42±0.01 |
| *A. paniculata* | 19.0 | 21.47±0.10 | 4.0 | 3.74±0.12 | ND | ND | 14.75±0.10 | 0.73±0.03 | 7.32±0.01 |
| *C. asiatica* | 17.0 | 18.15±0.19 | 1.0 | 1.24±0.73 | ND | ND | 11.44±0.09 | 0.53±0.38 | 6.11±0.08 |
| *P. indica* | 15.0 | 16.35±0.10 | 1.0 | 1.01±0.18 | ND | ND | 22.38±0.08 | ND | 5.88±0.77 |
| *C. hystrix* | 17.0 | 12.37±0.03 | 3.0 | 0.75±0.25 | ≥ 0.6 | 0.93±0.12 | 16.47±0.14 | 6.92±0.18 | 6.15±0.00 |
| **Stem** | | | | | | | | | |
| *T. crispa* | 9.0 | 9.37±0.30 | 1.0 | 1.12±0.03 | ND | ND | 13.65±0.04 | 34.87±0.02 | 6.60±0.00 |
| *C. verum* | 3.4 | 3.43±0.03 | 0.2 | 0.11±0.07 | ≥ 0.8 | 0.82±0.03 | 19.77±0.06 | 11.04±0.32 | 8.07±0.01 |
| *C. sappan* | 0.8 | 0.73±0.01 | 0.1 | ND | ND | ND | 55.03±0.05 | 0.81±0.12 | 5.83±0.06 |
| *D. scandens* | 10.0 | 7.52±0.08 | 4.0 | 0.31±0.08 | ND | ND | 30.17±0.12 | 15.45±.017 | 6.31±0.02 |

All values are expressed as mean ± SD, n=3, ND: Not detected

**4.3 Flow Properties**

The results of flow properties by measuring the repose angle, kawakita equation and flow rate were shown in Table 4.2. A large number of herbals have high values of repose angle and % compressibility ratio. It indicated the poor flowability (Table 4.3).

Kawakita plots (Plots of N/C versus N) for all herbal powders gave the linear relationship ($r^2 \geq 0.99$) (Fig 4.24). Kawakita constants (a and 1/b) represent herbal powder behavior from bulk density state to the tap density state. Most powder exhibited high compressible value (a) showing the poor flowability; however, there were three herbal powders having low compressible value: *P. nigrum* (0.169), *C. longa* (0.201) and *Z. officinale* (0.242). Hence, these types of herbal powder had better flowability than others. 1/b value represents cohesiveness of the herbal powder. *C. angustifolia* (147.674) had the highest 1/b value, thus exhibited the most cohesiveness (Table 4.2). Flow rate could not be calculated for every herbal powder. As a whole, the flowability of almost all herbal powder used in this study was poor. It suggested the application of granulation method for tablet formulation.

The analysis of relationship between herbal powder composition and flowability using Kawakita constant values by a quadratic model revealed that the model as fit was not statistically significant ($p > 0.05$). It could be considered that the derived properties of herbal powder such as particle size and shape were more influential factors than the composition in the powder itself.

In order to improve the flowability of the herbal powder, the wet granulation was applied using 4 types of binders, namely 10% starch paste (SP), 5% starch paste + 5% gelatin solution (SG), 10% polyvinylpyrrolidone (PP) and 10% gelatin solution (GT). The compressibility ratios of the obtained granules were summarized in Table 4.3. The flow property of the granule changed from poor or passable for powder to good or excellent for granules.

The exemplary microscopic photographs in Figure 4.25 showed the comparison in characteristics of herbal powder and granules. The significant improvement in particle size was obviously observed. Moreover, it is well known that the shapes of the particles also affect the flow property. Particles which are square or fiber particles with a long shape have more difficulty to flow when compared to

particles with round shape. It can be seen that herbal powder granules are more spherical (Fig 4.25) and then gave better flowability as demonstrated by the lower compressibility ratio (Table 4.3).

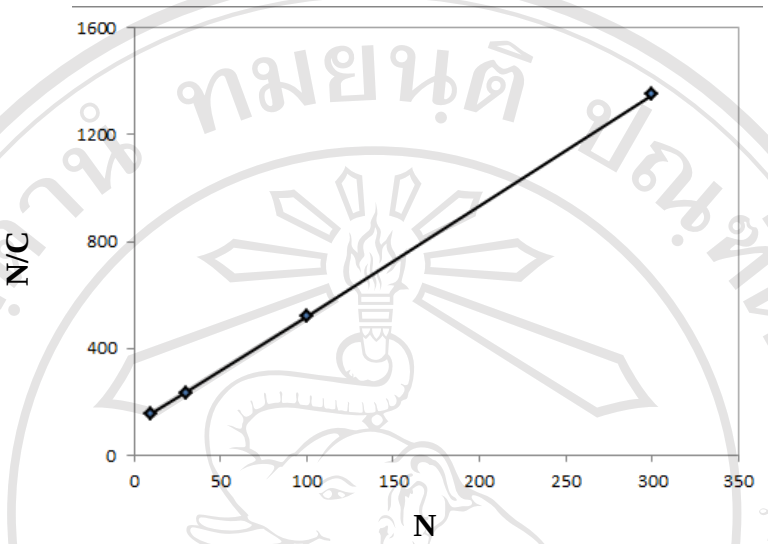



**Fig 4.24** Kawakita plot (Plot of N/C versus number of taps N) of *Z. officinale* powder

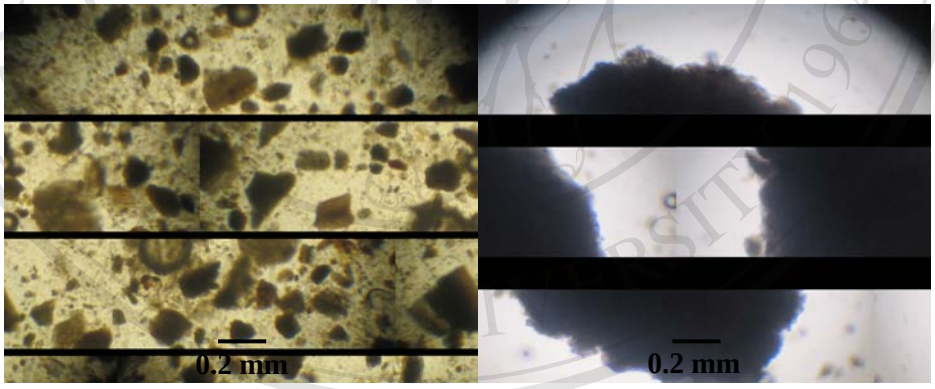



**Fig 4.25** Microscopic photographs of (a) herbal powder and (b) granule of *C. asiatica* leaf

**Table 4.2** Flow properties of herbal powder

| Sample Type | Kawakita analysis | | | | | Flow rate (g/s) | Repose angle | |
|---|---|---|---|---|---|---|---|---|
| | Slope (1/a) | a | Intercept (1/ab) | 1/b | $r^2$ | | (°) | Flow Property |
| **Fruit** | | | | | | | | |
| *P. emblica* | 2.171 | 0.461 | 68.460 | 31.534 | 0.997 | ND | 32±2.65 | passable |
| *S. trilobatum* | 2.683 | 0.373 | 101.400 | 37.794 | 0.997 | ND | 43±1.00 | very poor |
| *T. chebula* | 3.268 | 0.306 | 50.230 | 15.370 | 0.999 | ND | 44±0.58 | very poor |
| *P. nigrum* | 5.929 | 0.169 | 45.140 | 7.613 | 0.999 | ND | 42±0.58 | very poor |
| *M. citrifolia* | 2.978 | 0.336 | 44.134 | 14.822 | 0.997 | ND | 50±0.58 | very poor |
| **Underground part** | | | | | | | | |
| *Z. officinale* | 4.127 | 0.242 | 110.100 | 26.678 | 1.000 | ND | 50±1.73 | very poor |
| *C. longa* | 4.963 | 0.201 | 100.100 | 20.169 | 0.999 | ND | 48±0.58 | very poor |
| *A. calamus* | 2.629 | 0.380 | 61.930 | 23.556 | 0.997 | ND | 51±0.58 | very poor |
| *E. longifolia* | 2.621 | 0.382 | 109.700 | 41.854 | 0.995 | ND | 25±1.51 | good |
| *G. glabra* | 2.394 | 0.418 | 107.100 | 44.737 | 0.998 | ND | 42±1.73 | very poor |

**Table 4.2** Flow properties of herbal powder (cont.)

| Sample Type | Kawakita analysis | | | | | Flow rate (g/s) | Repose angle | |
|---|---|---|---|---|---|---|---|---|
| | Slope (1/a) | a | Intercept (1/ab) | 1/b | $r^2$ | | (°) | Flow Property |
| **Leaf** | | | | | | | | |
| *C. angustifolia* | 1.806 | 0.554 | 266.700 | 147.674 | 0.891 | ND | 46±0.58 | very poor |
| *A. paniculata* | 2.694 | 0.371 | 101.900 | 37.825 | 0.997 | ND | 29±1.81 | good |
| *C. asiatica* | 2.310 | 0.433 | 81.570 | 35.312 | 0.996 | ND | 31±2.52 | passable |
| *P. indica* | 3.290 | 0.304 | 70.340 | 21.380 | 0.999 | ND | 39±2.03 | passable |
| *C. hystrix* | 2.745 | 0.364 | 60.440 | 22.018 | 0.999 | ND | 39±1.00 | passable |
| **Stem** | | | | | | | | |
| *T. crispa* | 2.655 | 0.377 | 96.430 | 36.320 | 0.998 | ND | 30±1.15 | good |
| *C. verum* | 2.103 | 0.476 | 92.780 | 44.118 | 0.993 | ND | 35±0.58 | passable |
| *C. sappan* | 2.747 | 0.364 | 104.700 | 38.114 | 0.999 | ND | 41±1.00 | very poor |
| *D. scandens* | 3.300 | 0.303 | 115.700 | 35.061 | 0.999 | ND | 40±1.93 | passable |

All values are expressed as mean ± SD, n=3

ND: Not determinded (Determination was not possible due to powder could not flow through the funnel orifice)

**Table 4.3** Compressibility ratio of herbal powder and herbal granules using different binders

| Sample Type | No binder | | SP | | SG | | PP | | GT | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Compressibility Ratio (%) | Flow Property | Compressibility Ratio (%) | Flow Property | Compressibility Ratio (%) | Flow Property | Compressibility Ratio (%) | Flow Property | Compressibility Ratio (%) | Flow Property |
| **Fruit** | | | | | | | | | | |
| *P. emblica* | 29±5.74 | poor | 10.20±2.29 | good | 9.28±1.86 | excellent | 10.20±2.35 | good | 8.25±1.17 | excellent |
| *S. trilobatum* | 24±2.78 | passable | 11.58±0.43 | good | 10.53±1.41 | good | 11.46±1.07 | good | 10.42±2.16 | good |
| *T. chebula* | 24±0.77 | passable | 11.22±3.09 | good | 10.23±2.42 | good | 11.44±1.54 | good | 10.27±0.45 | good |
| *P. nigrum* | 25±0.19 | passable | 10.53±0.68 | good | 9.47±1.64 | excellent | 10.42±0.56 | good | 9.38±0.67 | excellent |
| *M. citrifolia* | 23±1.26 | passable | 11.88±1.66 | good | 10.14±1.58 | good | 11.50±1.95 | good | 10.81±1.60 | good |
| **Underground part** | | | | | | | | | | |
| *Z. officinale* | 15±0.74 | fair | 8.51±0.81 | excellent | 8.51±1.54 | excellent | 7.45±0.95 | excellent | 6.45±1.23 | excellent |
| *C. longa* | 15±0.77 | fair | 9.28±1.67 | excellent | 8.33±2.68 | excellent | 9.28±1.57 | excellent | 8.42±1.51 | excellent |
| *A. calamus* | 22±1.07 | passable | 10.42±0.55 | good | 9.47±1.52 | excellent | 9.38±1.86 | excellent | 7.45±1.31 | excellent |
| *E. longifolia* | 29±2.08 | poor | 10.53±2.59 | good | 9.47±2.43 | excellent | 10.53±1.65 | good | 9.57±2.38 | excellent |
| *G. glabra* | 33±0.54 | very poor | 8.51±1.71 | excellent | 7.45±0.77 | excellent | 8.51±2.19 | excellent | 8.51±1.26 | excellent |

**Table 4.3** Compressibility ratio of herbal powder and herbal granules using different binders (cont.)

| Sample Type | No binder | | SP | | SG | | PP | | GT | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Compressibility Ratio (%) | Flow Property | Compressibility Ratio (%) | Flow Property | Compressibility Ratio (%) | Flow Property | Compressibility Ratio (%) | Flow Property | Compressibility Ratio (%) | Flow Property |
| **Leaf** | | | | | | | | | | |
| *C. angustifolia* | 16±3.46 | fair | 9.28±2.15 | excellent | 8.33±2.64 | excellent | 9.28±0.31 | excellent | 10.31±2.52 | good |
| *A. paniculata* | 22±3.77 | passable | 10.53±1.17 | good | 9.47±0.81 | excellent | 11.46±0.88 | good | 11.46±0.62 | good |
| *C. asiatica* | 25±4.22 | poor | 12.37±3.24 | good | 9.38±0.74 | excellent | 11.34±2.19 | good | 11.34±1.24 | good |
| *P. indica* | 21±4.09 | passable | 10.71±2.01 | good | 9.43±1.24 | excellent | 10.91±3.17 | good | 10.75±0.48 | good |
| *C. hystrix* | 23±1.61 | passable | 7.53±0.32 | excellent | 6.38±0.59 | excellent | 9.47±1.32 | excellent | 11.46±1.39 | good |
| **Stem** | | | | | | | | | | |
| *T. crispa* | 27±3.02 | poor | 10.42±1.16 | good | 10.31±3.30 | good | 11.34±1.85 | good | 9.38±1.02 | excellent |
| *C. verum* | 25±2.05 | poor | 10.31±2.88 | good | 10.31±1.81 | good | 10.31±2.44 | good | 8.33±2.19 | excellent |
| *C. sappan* | 27±3.27 | poor | 10.64±0.74 | good | 10.53±2.77 | good | 11.58±1.97 | good | 9.57±1.06 | excellent |
| *D. scandens* | 26±4.95 | poor | 13.04±1.66 | good | 12.90±2.62 | good | 13.98±2.10 | good | 11.96±1.66 | good |

All values are expressed as mean ± SD, n=3

**4.4 Compaction property**

The compaction property of the herbal powder was evaluated by measuring the hardness of tablets compressed with a 15,000 N compression force, and the results are shown in Table 4.4. It was found that no compacted powder had hardness of over 40 N. Thus, it can be indicated that all herbal powder was not compressible enough for tablet production using direct compression or dry granulation. Therefore, it was obvious from the results of this study that wet granulation method was the most appropriate method in formulation of herbal powder tablets.

The analysis of relationship between herbal powder composition and compressibility using hardness value of tablets as a statistical tool in quadratic model revealed the following equation.

$$\text{Hardness} = 3.291 - 0.221X_1 + 0.027X_2 - 1.272X_3 + 0.004X_1^2 - 0.002X_2^2 - 0.005X_3^2 + 0.003X_1X_2 - 0.024X_1X_3 + 0.041X_2X_3$$

The coefficient of determination ($r^2$) of the regression equation was 0.920, indicating that the model as fitted explained 92.00% of the variability in hardness. The adjusted $r^2$ for this equation model was 0.840 (sig = 0.001). According to this finding, it can be concluded that fiber, starch and volatile oil content are statistical significantly related to the hardness of tablet ($p < 0.05$).

**Table 4.4** Hardness of the herbal tablets compressed with a 15,000 N compression force

| Sample Type | Hardness (N) | Sample Type | Hardness (N) |
|---|---|---|---|
| **Fruit** | | **Underground part** | |
| *P. emblica* | ND | *Z. officinale* | 4.71±0.08 |
| *S. trilobatum* | 4.12±0.10 | *C. longa* | 17.06±0.28 |
| *T. chebula* | 5.39±0.04 | *A. calamus* | 2.55±0.05 |
| *P. nigrum* | 3.14±0.03 | *E. longifolia* | 1.86±0.03 |
| *M. citrifolia* | 2.75±0.05 | *G. glabra* | 18.73±0.31 |
| **Leaf** | | **Stem** | |
| *C. angustifolia* | 15.69±0.17 | *T. crispa* | 4.02±0.04 |
| *A. paniculata* | 11.77±0.31 | *C. verum* | 3.92±0.09 |
| *C. asiatica* | 17.06±0.19 | *C. sappan* | 34.12±0.17 |
| *P. indica* | 7.35±0.09 | *D. scandens* | 16.87±0.22 |
| *C. hystrix* | ND | | |

All values are expressed as mean ± SD, n=6, ND: Not determinded

**4.5 Formulation of herbal powders**

From herbal flowability and compactability tests, it can be concluded that all herbal powders were not compressible enough for tablet production using direct compression or dry granulation. Therefore, wet granulation method is the most appropriate method in formulation of herbal powder tablets. First of all, the adequacy of the lubricant in the formulation was investigated. The concentrations of glidant and lubricant used in the general formulation i.e, talcum 3% and magnesium stearate 0.5% were investigated by studying the maximum compression forces detected at the upper and lower punches during tablet compression as illustrated in Figure 4.26. The interpretation is based on the fact that if the compression force generated from the upper punch can transmitted effectively to the lower punch, or the compression force at the lower punch has a value closed to that of the upper punch, glidant and lubricant are present in sufficient concentrations in the system and the friction between granules or granules and die wall are minimized. The transmission ratio (R) or the ratio of the maximum upper punch force devided by the maximum lower puch force was used to represent the efficiency of the glidant and lubricant in the formulation. The results are shown in Table 4.5. It is obvious that all formulations had the transmission ratio of greater than 0.9, indicating that sufficient lubrication was available in all herbal formulations. Morover, the smooth and glossy surface was observed on the sides of the tablets. Therefore, it can be concluded that the concentrations of talcum and magnesium stearate at 3 % and 0.5 % were appropriate for all types of formulations in this study.

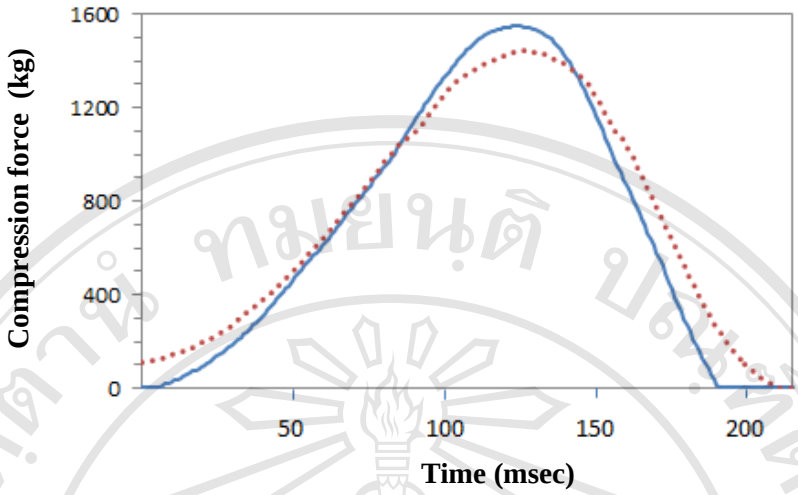



**Fig 4.26** Examplary compression profile of *T. crispa* powder obtained from instrumented tableting machine
(— upper punch force and ····· lower punch force)

**Table 4.5** The maximum lower and upper punch force and the pressure transmission ratio (R) of herbal tablet formulations using different binders

| Sample Type | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum Lower Punch Force (N) | Maximum Upper Punch Force (N) | R | Maximum Lower Punch Force (N) | Maximum Upper Punch Force (N) | R | Maximum Lower Punch Force (N) | Maximum Upper Punch Force (N) | R | Maximum Lower Punch Force (N) | Maximum Upper Punch Force (N) | R |
| **Fruit** | | | | | | | | | | | | |
| *P. emblica* | 14581 ±548 | 15201 ±498 | 0.97 | 15778 ±163 | 15994 ±192 | 0.99 | 15323 ±352 | 15753 ±298 | 0.97 | 15333 ±249 | 15410 ±299 | 1.00 |
| *S. trilobatum* | 15996 ±365 | 15575 ±312 | 0.94 | 15541 ±253 | 15333 ±324 | 1.01 | 15944 ±232 | 15863 ±326 | 1.01 | 15266 ±405 | 15554 ±313 | 0.98 |
| *T. chebula* | 15725 ±231 | 16344 ±346 | 1.02 | 14701 ±448 | 15742 ±574 | 0.93 | 15681 ±332 | 15732 ±265 | 1.00 | 15334 ±398 | 16121 ±316 | 0.95 |
| *P. nigrum* | 16064 ±256 | 15309 ±342 | 1.00 | 15352 ±409 | 16091 ±347 | 0.95 | 15929 ±635 | 15325 ±513 | 1.04 | 15302 ±266 | 15845 ±327 | 0.97 |
| *M. citrifolia* | 15794 ±462 | 15437 ±574 | 0.99 | 15516 ±363 | 16125 ±286 | 0.96 | 15618 ±532 | 16814 ±465 | 0.93 | 14695 ±402 | 15333 ±516 | 0.96 |
| **Underground part** | | | | | | | | | | | | |
| *Z. officinale* | 15873 ±237 | 16438 ±307 | 0.97 | 15605 ±374 | 15879 ±399 | 0.98 | 15577 ±691 | 16880 ±546 | 0.92 | 15087 ±265 | 15633 ±272 | 0.97 |
| *C. longa* | 14865 ±461 | 15876 ±378 | 0.94 | 15585 ±352 | 15759 ±339 | 0.99 | 15475 ±157 | 15525 ±217 | 1.00 | 15431 ±195 | 15902 ±325 | 0.97 |
| *A. calamus* | 15823 ±234 | 15485 ±364 | 1.02 | 15144 ±272 | 15198 ±275 | 1.00 | 15312 ±314 | 15860 ±464 | 0.97 | 14492 ±351 | 15370 ±409 | 0.94 |
| *E. longifolia* | 15922 ±183 | 15914 ±241 | 1.00 | 15383 ±538 | 15855 ±442 | 0.97 | 15541 ±398 | 15844 ±334 | 0.98 | 15213 ±187 | 15657 ±249 | 0.97 |
| *G. glabra* | 15292 ±353 | 15413 ±419 | 0.99 | 15152 ±236 | 15282 ±322 | 0.99 | 15404 ±341 | 15373 ±287 | 1.00 | 15733 ±373 | 16024 ±449 | 0.98 |

**Table 4.5** The maximum lower and upper punch force and the pressure transmission ratio (R) of herbal tablet formulations using different binders (cont.)

| Sample Type | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum Lower Punch Force (N) | Maximum Upper Punch Force (N) | R | Maximum Lower Punch Force (N) | Maximum Upper Punch Force (N) | R | Maximum Lower Punch Force (N) | Maximum Upper Punch Force (N) | R | Maximum Lower Punch Force (N) | Maximum Upper Punch Force (N) | R |
| **Leaf** | | | | | | | | | | | | |
| *C. angustifolia* | 14541 ±472 | 15962 ±364 | 0.91 | 15271 ±355 | 15951 ±299 | 0.96 | 15023 ±417 | 15517 ±487 | 0.97 | 16265 ±427 | 15925 ±448 | 1.02 |
| *A. paniculata* | 15415 ±206 | 15781 ±308 | 0.98 | 14972 ±231 | 15034 ±285 | 1.00 | 15413 ±275 | 15887 ±326 | 0.97 | 15148 ±314 | 15432 ±213 | 0.98 |
| *C. asiatica* | 14801 ±397 | 15632 ±325 | 0.95 | 14159 ±185 | 15513 ±249 | 0.91 | 15401 ±123 | 15628 ±206 | 0.99 | 16269 ±277 | 15865 ±346 | 1.03 |
| *P. indica* | 15370 ±147 | 15583 ±234 | 0.99 | 15738 ±532 | 14944 ±624 | 1.05 | 15746 ±343 | 16131 ±253 | 0.98 | 15350 ±291 | 15751 ±259 | 0.97 |
| *C. hystrix* | 15475 ±567 | 16274 ±671 | 0.95 | 15067 ±264 | 15197 ±402 | 0.99 | 15477 ±258 | 15386 ±371 | 1.01 | 15867 ±346 | 15900 ±.16 | 1.00 |
| **Stem** | | | | | | | | | | | | |
| *T. crispa* | 15059 ±246 | 15172 ±219 | 0.99 | 15496 ±459 | 15804 ±385 | 0.98 | 15252 ±385 | 15593 ±307 | 0.98 | 15690 ±559 | 15937 ±481 | 0.98 |
| *C. verum* | 15378 ±119 | 15394 ±187 | 1.00 | 15525 ±214 | 15746 ±284 | 0.99 | 15755 ±293 | 16102 ±387 | 0.98 | 15586 ±324 | 15725 ±255 | 0.99 |
| *C. sappan* | 15306 ±338 | 15543 ±419 | 0.98 | 15753 ±429 | 16173 ±395 | 0.97 | 15629 ±272 | 16096 ±415 | 0.97 | 15318 ±118 | 15495 ±231 | 0.99 |
| *D. scandens* | 14872 ±223 | 15007 ±247 | 0.99 | 15782 ±335 | 15437 ±433 | 1.02 | 15277 ±233 | 15667 ±254 | 0.98 | 15474 ±259 | 15756 ±211 | 0.98 |

All values are expressed as mean ± SD, n=6

The formulation development can be divided into 9 phases.

**4.5.1 Development Phase I** Effect of binders at a compression force of 15,000 N

Because of poor flowability and compactability of herbal powder, pharmaceutical excipients as well as the wet granulation process were required to enhance the powder properties. The basic formulation below was applied to study the effect of 4 types of binders, namely 10% starch paste (SP), 5% starch paste + 5% gelatin solution (SG), 10% polyvinylpyrrolidone (PP) and 10% gelatin solution (GT) on hardness of tablets. Magnesium stearate served as a lubricant during tableting. Purified talcum was employed as both glidant and antiadherant.

The basic formulation was as follows:

**Formulation**

| | Amount per tablet (mg) |
|---|---|
| Herbal powder | 449.50 |
| Binder | 33.00 |
| Talcum | 15.00 |
| Magnesium stearate | 2.50 |
| **Compression force** | 15,000 N |

The compression was performed with the instrumented tabletting machine by starting with a compression force of 15,000 N. The properties of formulated tablets are complied in Table 4.6.

It can be observed from Table 4.6 that formulations that had the hardness of greater than 40 N were as follows:

**Fruit**

*S. trilobatum*: SP(47.74±0.14 N) and GT(44.13±0.07 N)

**Underground part**

*E. longifolia*: PP(74.36±0.17 N)

**Stem**

*C. verum*: SP(57.01±0.16 N), SG(55.41±0.3 N), PP(85.64±0.50 N) and

GT(43.80±0.22 N)

*C. sappan*: SG(50.86±0.27 N), PP(75.14±0.51 N) and GT(45.78±0.06 N)

*D. scandens*: SP(71.66±0.54 N), PP(51.93±0.58 N) and GT(54.77±0.54 N)

Three types of herbal tablet formulations from stem had the hardness exceeding 40 N, while there were no tablet produced from leaf had the average hardness of more than 40 N. Each type of binder provides tablet with different hardness and disintegration property. The formulations with hardness of more than 40 N were evaluated for quality control in the next step.

**Table 4.6** Hardness, weight and disintegration time of herbal tablets prepared using different binders compressed at 15,000 N (n = 6)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Fruit** | | | | | | | | | | | | |
| *P. emblica* | 13.00 ±0.08 | 0.5076 ±0.01 | – | 22.48 ±0.16 | 0.5033 ±0.01 | – | 29.99 ±0.20 | 0.5033 ±0.01 | – | 11.02 ±0.06 | 0.5195 ±0.00 | – |
| *S. trilobatum* | 47.74 ±0.14 | 0.4216 ±0.00* | 0.91 ±0.29 | 18.82 ±0.03 | 0.3974 ±0.01* | – | 27.80 ±0.05 | 0.4089 ±0.00* | – | 44.13 ±0.07 | 0.4016 ±0.00* | 0.54 ±0.05 |
| *T. chebula* | 24.62 ±0.10 | 0.5085 ±0.00 | – | 31.16 ±0.10 | 0.4933 ±0.00 | – | 34.24 ±0.17 | 0.5106 ±0.01 | – | 22.81 ±0.12 | 0.5134 ±0.00 | – |
| *P. nigrum* | 15.12 ±0.12 | 0.5126 ±0.01 | – | 10.37 ±0.07 | 0.4871 ±0.00 | – | 17.54 ±0.17 | 0.4987 ±0.00 | – | 11.36 ±0.07 | 0.5241 ±0.00 | – |
| *M. citrifolia* | 5.85 ±0.44 | 0.4744 ±0.00 | – | 8.03 ±0.10 | 0.5043 ±0.00 | – | 4.09 ±0.06 | 0.5045 ±0.00 | – | 6.02 ±0.04 | 0.5045 ±0.01 | – |
| **Underground part** | | | | | | | | | | | | |
| *Z. officinale* | 12.99 ±0.12 | 0.5211 ±0.01 | – | 7.46 ±0.07 | 0.5002 ±0.00 | – | 38.08 ±0.18 | 0.5154 ±0.01 | – | 16.74 ±0.10 | 0.5054 ±0.00 | – |
| *C. longa* | 26.65 ±0.14 | 0.4872 ±0.01 | – | 25.57 ±0.18 | 0.5059 ±0.00 | – | 20.39 ±0.14 | 0.5069 ±0.00 | – | 28.73 ±0.11 | 0.5168 ±0.00 | – |
| *A. calamus* | 13.30 ±0.24 | 0.4958 ±0.01 | – | 12.3 ±0.09 | 0.4852 ±0.00 | – | 10.69 ±0.08 | 0.5144 ±0.00 | – | 20.28 ±0.20 | 0.4946 ±0.00 | – |
| *E. longifolia* | 26.98 ±0.09 | 0.4095 ±0.00* | – | 19.51 ±0.10 | 0.3899 ±0.00* | – | 74.36 ±0.17 | 0.5163 ±0.00 | 9.53 ±0.04 | 32.37 ±0.24 | 0.4177 ±0.01* | – |
| *G. glabra* | 26.32 ±0.27 | 0.5010 ±0.00 | – | 24.62 ±0.22 | 0.5028 ±0.00 | – | 13.01 ±0.19 | 0.4895 ±0.01 | – | 28.25 ±0.26 | 0.5252 ±0.01 | – |

**Table 4.6** Hardness, weight and disintegration time of herbal tablets prepared using different binders compressed at 15,000 N (n = 6) (cont.)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Leaf** | | | | | | | | | | | | |
| *C. angustifolia* | 11.33 ±0.14 | 0.4915 ±0.01 | – | 11.94 ±0.26 | 0.4901 ±0.00 | – | 7.68 ±0.12 | 0.5124 ±0.00 | – | 9.89 ±0.13 | 0.5160 ±0.00 | – |
| *A. paniculata* | 34.30 ±0.20 | 0.4971 ±0.01 | – | 32.41 ±0.17 | 0.4907 ±0.00 | – | 38.74 ±0.15 | 0.5131 ±0.01 | – | 27.80 ±0.12 | 0.5102 ±0.00 | – |
| *C. asiatica* | 32.56 ±0.36 | 0.4979 ±0.01 | – | 31.20 ±0.25 | 0.5070 ±0.01 | – | 17.18 ±0.26 | 0.4979 ±0.01 | – | 17.10 ±0.07 | 0.5103 ±0.01 | – |
| *P. indica* | 13.51 ±0.17 | 0.5111 ±0.01 | – | 19.95 ±0.07 | 0.4156 ±0.01* | – | 22.04 ±0.03 | 0.5056 ±0.02 | – | 22.11 ±0.05 | 0.4049 ±0.00* | – |
| *C. hystrix* | 13.34 ±0.07 | 0.4926 ±0.00 | – | 5.33 ±0.06 | 0.4817 ±0.00 | – | 25.65 ±0.19 | 0.4881 ±0.01 | – | 23.48 ±0.15 | 0.5119 ±0.01 | – |
| **Stem** | | | | | | | | | | | | |
| *T. crispa* | 26.98 ±0.17 | 0.5233 ±0.01 | – | 32.25 ±0.07 | 0.5117 ±0.01 | – | 35.03 ±0.36 | 0.5158 ±0.01 | – | 21.88 ±0.17 | 0.5171 ±0.01 | – |
| *C. verum* | 57.01 ±0.16 | 0.5025 ±0.00 | 5.03 ±0.03 | 55.41 ±0.3 | 0.5141 ±0.01 | 4.42 ±0.54 | 85.64 ±0.50 | 0.5030 ±0.01 | 2.17 ±0.11 | 43.80 ±0.22 | 0.5096 ±0.01 | 6.56 ±1.02 |
| *C. sappan* | 24.49 ±0.06 | 0.4163 ±0.01* | – | 50.86 ±0.27 | 0.4108 ±0.01* | 0.56 ±0.03 | 75.14 ±0.51 | 0.5241 ±0.00 | 2.55 ±0.40 | 45.78 ±0.06 | 0.3918 ±0.00* | 0.53 ±0.01 |
| *D. scandens* | 71.66 ±0.54 | 0.4924 ±0.02 | 5.28 ±0.15 | 35.22 ±0.15 | 0.4097 ±0.00* | – | 51.93 ±0.58 | 0.4504 ±0.03 | 5.44 ±0.56 | 54.77 ±0.54 | 0.4036 ±0.01* | 4.44 ±0.57 |

* Tablets formulation was prepared as a 400 mg/tablet because granules had low bulk density,

All values are expressed as mean ± SD, DT: Disintegration time

**4.5.2 Development Phase II** Effect of binders at a compression force of 20,000 N

The basic formulation from phase I that had the hardness of more than 20 N, but less than 40 N (Table 4.6) was compressed at a compression force of 20,000 N. The results were shown in Table 4.7.

**Formulation**

| | Amount per tablet (mg) |
|---|---|
| Herbal powder | 449.50 |
| Binder | 33.00 |
| Talcum | 15.00 |
| Magnesium stearate | 2.50 |
| **Compression force** | 20,000 N |

The effect of increase in compression force from 15,000 N to 20,000 N on the hardness was slight for most herbal powder. Only one herbal powder that achieved the hardness of more than 40 N was:

**Leaf**

*A. paniculata*: SP(42.22±2.19 N), SG(44.54±1.49 N) and PP(49.25±2.06 N) (Table 4.7)

It can be considered that modification of the formulation was necessary to conduct in order to improve the tablet hardness.

**Table 4.7** Hardness, weight and disintegration time of herbal tablets prepared using different binders compressed at 20,000 N (n = 6)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Fruit** | | | | | | | | | | | | |
| *P. emblica* | – | – | – | 25.03 ±0.14 | 0.5044 ±0.01 | – | 32.67 ±4.47 | 0.5051 ±0.01 | – | – | – | – |
| *S. trilobatum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *T. chebula* | 28.95 ±1.87 | 0.5148 ±0.00 | – | 32.90 ±2.46 | 0.5231 ±0.01 | – | 36.90 ±2.43 | 0.4999 ±0.01 | – | 28.66 ±2.07 | 0.5085 ±0.01 | – |
| *P. nigrum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *M. citrifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| **Underground part** | | | | | | | | | | | | |
| *Z. officinale* | – | – | – | – | – | – | 21.65 ±3.11 | 0.5075 ±0.01 | – | – | – | – |
| *C. longa* | 23.73 ±0.96 | 0.4973 ±0.01 | – | 30.00 ±2.47 | 0.5080 ±0.00 | – | 18.85 ±2.03 | 0.5066 ±0.00 | – | 35.77 ±2.45 | 0.5080 ±0.01 | – |
| *A. calamus* | – | – | – | – | – | – | – | – | – | 25.83 ±0.85 | 0.5193 ±0.00 | – |
| *E. longifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| *G. glabra* | 29.03 ±2.80 | 0.5118 ±0.01 | – | 27.28 ±1.64 | 0.5132 ±0.67 | – | – | – | – | 26.18 ±2.39 | 0.5177 ±0.01 | – |

**Table 4.7** Hardness, weight and disintegration time of herbal tablets prepared using different binders compressed at 20,000 N (n = 6) (cont.)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Leaf** | | | | | | | | | | | | |
| *C. angustifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| *A. paniculata* | 42.22 ±2.19 | 0.5115 ±0.00 | 6.13 ±1.75 | 44.54 ±1.49 | 0.5074 ±0.00 | 5.26 ±0.08 | 49.25 ±2.06 | 0.5127 ±0.01 | 42.52 ±9.36 | – | – | – |
| *C. asiatica* | 21.40 ±3.12 | 0.4944 ±0.02 | – | 32.23 ±2.63 | 0.5153 ±0.02 | – | – | – | – | – | – | – |
| *P. indica* | – | – | – | – | – | – | 33.03 ±0.99 | 0.5101 ±0.00 | – | 27.88 ±0.56 | 0.4193 ±0.01* | – |
| *C. hystrix* | – | – | – | – | – | – | 25.93 ±1.15 | 0.4852 ±0.00 | – | 21.40 ±1.70 | 0.4959 ±0.00 | – |
| **Stem** | | | | | | | | | | | | |
| *T. crispa* | 31.78 ±3.57 | 0.5159 ±0.00 | – | 35.05 ±2.37 | 0.5238 ±0.01 | – | 37.07 ±2.69 | 0.5212 ±0.01 | – | 28.92 ±2.86 | 0.5213 ±0.01 | – |
| *C. verum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. sappan* | – | – | – | – | – | – | – | – | – | – | – | – |
| *D. scandens* | – | – | – | – | – | – | – | – | – | – | – | – |

* Tablets formulation was prepared as a 400 mg/tablet because granules had low bulk density,

All values are expressed as mean ± SD, DT: Disintegration time

**4.5.3 Development Phase III** Effect of adding microcrystalline cellulose at a concentration of 20%

The formulations that had hardness below 40 N from development phase II were improved by adding microcrystalline cellulose (MCC) to a concentration of 20% of the formulation. Microcrystalline cellulose (Avicel PH101®) was used as a filler and binder because of its unique compressibility and creates tablets that are very hard and yet disintegrate rapidly. Then, the formulation was compressed at 15,000 N.

**Formulation**

| | Amount per tablet (mg) |
|---|---|
| Herbal powder | 329.50 |
| Binder | 53.00 |
| Microcrystaline cellulose (MCC) | 100.00 |
| Talcum | 15.00 |
| Magnesium stearate | 2.50 |
| **Compression force** | 15,000 N |

Formulations that had the hardness of more than 40 N (Table 4.8) were

**Fruit**

*T. chebula*: PP(42.72±7.29 N)

**Leaf**

*P. indica*: SP(45.15±3.49 N), SG(43.18±3.07 N), PP(44.38±3.57 N) and GT(45.00±2.59 N)

It can be obviously seen from Table 4.8 that addition of MCC at a concentration of 20% of the formulation led to the increase in tablet hardness of some formulations. The remaining formulations were compressed at 20,000 N.

**Table 4.8** Hardness, weight and disintegration time of herbal tablets prepared using different binders and 20% MCC compressed at 15,000 N (n = 6)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Fruit** | | | | | | | | | | | | |
| *P. emblica* | – | – | – | 33.41 ±1.95 | 0.5079 ±0.00 | – | 37.95 ±2.36 | 0.5102 ±0.00 | – | – | – | – |
| *S. trilobatum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *T. chebula* | – | – | – | 37.80 ±0.97 | 0.5105 ±0.00 | – | 42.72 ±7.29 | 0.5079 ±0.01 | 9.52 ±0.87 | – | – | – |
| *P. nigrum* | 15.57 ±1.65 | 0.5105 ±0.00 | – | 14.97 ±1.57 | 0.5133 ±0.00 | – | 13.33 ±1.66 | 0.5042 ±0.01 | – | 13.17 ±1.53 | 0.5150 ±0.00 | – |
| *M. citrifolia* | 8.63 ±0.97 | 0.5027 ±0.00 | – | 9.70 ±0.98 | 0.5038 ±0.00 | – | 10.43 ±2.48 | 0.5033 ±0.00 | – | 10.03 ±0.69 | 0.4917 ±0.01 | – |
| **Underground part** | | | | | | | | | | | | |
| *Z. officinale* | 25.05 ±3.43 | 0.5147 ±0.01 | – | 24.95 ±3.24 | 0.5094 ±0.01 | – | 31.80 ±2.59 | 0.5092 ±0.01 | – | 25.17 ±2.81 | 0.5053 ±0.00 | – |
| *C. longa* | 17.50 ±1.27 | 0.5082 ±0.00 | – | 25.00 ±3.08 | 0.5123 ±0.00 | – | 12.37 ±2.38 | 0.5074 ±0.00 | – | 28.12 ±2.58 | 0.5091 ±0.00 | – |
| *A. calamus* | 33.37 ±1.87 | 0.5131 ±0.00 | – | 31.70 ±1.36 | 0.5024 ±0.00 | – | 31.27 ±1.42 | 0.5064 ±0.00 | – | 29.45 ±3.15 | 0.5024 ±0.01 | – |
| *E. longifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| *G. glabra* | 17.57 ±2.12 | 0.4983 ±0.00 | – | 26.75 ±2.19 | 0.5094 ±0.01 | – | 17.18 ±2.38 | 0.4930 ±0.00 | – | 13.57± 0.01 | 0.4826 ±0.00 | – |

**Table 4.8** Hardness, weight and disintegration time of herbal tablets prepared using different binders and 20% MCC compressed at 15,000 N (n = 6) (cont.)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Leaf** | | | | | | | | | | | | |
| *C. angustifolia* | 15.45 ±3.13 | 0.4977 ±0.01 | – | 12.43 ±2.00 | 0.4961 ±0.00 | – | 11.70 ±2.67 | 0.5017 ±0.01 | – | 13.57 ±2.22 | 0.4864 ±0.01 | – |
| *A. paniculata* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. asiatica* | 15.98 ±2.07 | 0.4972 ±0.00 | – | 26.08 ±2.90 | 0.5045 ±0.01 | – | 16.12 ±3.27 | 0.4896 ±0.00 | – | 21.58 ±3.18 | 0.5138 ±0.00 | – |
| *P. indica* | 45.15 ±3.49 | 0.5236 ±0.01 | 0.58 ±0.34 | 43.18 ±3.07 | 0.5172 ±0.00 | 1.18 ±0.03 | 44.38 ±3.57 | 0.4867 ±0.02 | 1.49 ±0.09 | 45.00 ±2.59 | 0.5137 ±.0.01 | 0.50 ±0.01 |
| *C. hystrix* | 33.38 ±2.60 | 0.5080 ±0.01 | – | 35.58 ±3.13 | 0.5115 ±0.00 | – | 39.17 ±2.35 | 0.4997 ±0.01 | – | 37.18 ±2.05 | 0.5123 ±0.00 | – |
| **Stem** | | | | | | | | | | | | |
| *T. crispa* | 33.13 ±2.11 | 0.5015 ±0.01 | – | 38.26 ±3.20 | 0.5016 ±0.00 | – | 38.32 ±1.85 | 0.5114 ±0.01 | – | 31.54 ±3.33 | 0.5129 ±0.00 | – |
| *C. verum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. sappan* | – | – | – | – | – | – | – | – | – | – | – | – |
| *D. scandens* | – | – | – | – | – | – | – | – | – | – | – | – |

All values are expressed as mean ± SD, DT: Disintegration time

**4.5.4 Development Phase IV** Effect of adding microcrystalline cellulose at a concentration of 20% in combination with a compression force of 20,000 N

**Formulation**

| | Amount per tablet (mg) |
|---|---|
| Herbal powder | 329.50 |
| Binder | 53.00 |
| Microcrystaline cellulose (MCC) | 100.00 |
| Talcum | 15.00 |
| Magnesium stearate | 2.50 |
| **Compression force** | 20,000 N |

The formulations from development phase III that had the hardness of more than 20 N, but less than 40 N (Table 4.8) was compressed at 20,000 N. The results are shown in Table 4.9. Formulations that had the tablet hardness of more than 40 N were as follows:

**Fruit**

*P. emblica*: PP(42.17±3.12 N)

**Underground part**

*Z. officinale*: PP(44.33±2.59 N)

*C. longa*: GT(45.40±1.96 N)

*G. glabra*: SG(44.33±2.51 N)

**Leaf**

*C. asiatica*: SG(43.63±2.18 N)

*C. hystrix*: SP(43.03±5.67 N), SG(43.67±1.22 N), PP(41.93±2.96 N) and GT(51.50±3.13 N)

**Stem**

*T. crispa*: SP(41.09±2.75 N), SG(41.50±1.91 N), PP(45.45±2.48 N) and GT(41.79±3.61 N)

A lot of formulation showed acceptable hardness in this stage with the combination of adding MCC and compression at a high compression force of 20,000 N. The remaining formulations were further improved by adding a higher concentration of either binder or MCC into the formulations in the following stages.

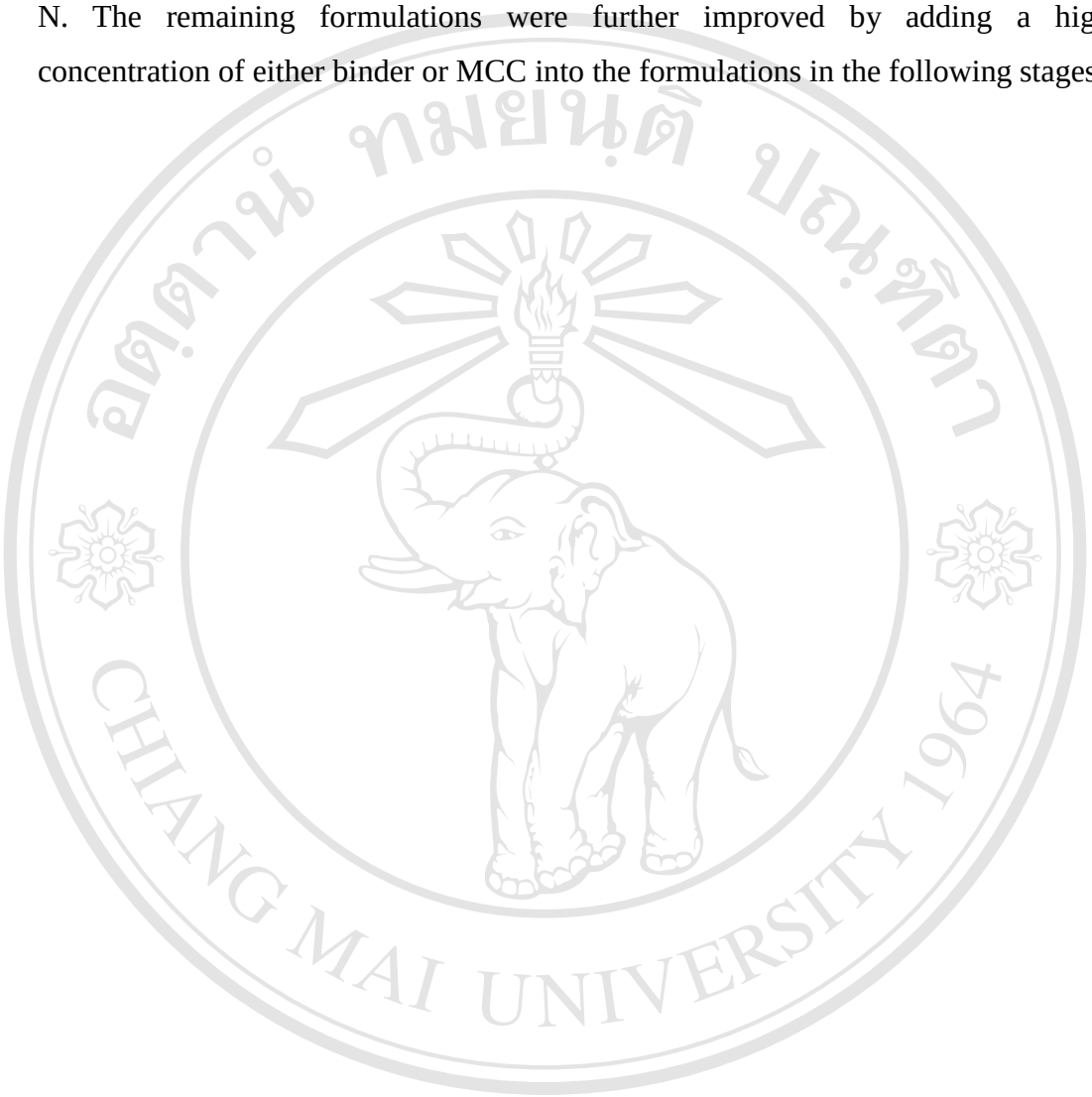


**Table 4.9** Hardness, weight and disintegration time of herbal tablets prepared using different binders and 20% MCC compressed at 20,000 N (n = 6)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Fruit** | | | | | | | | | | | | |
| *P. emblica* | – | – | – | 37.32 ±1.56 | 0.5012 ±0.00 | – | 42.17 ±3.12 | 0.5016 ±0.00 | 6.42 ±2.26 | – | – | – |
| *S. trilobatum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *T. chebula* | – | – | – | – | – | – | – | – | – | – | – | – |
| *P. nigrum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *M. citrifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| **Underground part** | | | | | | | | | | | | |
| *Z. officinale* | 30.90 ±1.04 | 0.5120 ±0.00 | – | 33.97 ±1.25 | 0.4770 ±0.00 | – | 44.33 ±2.59 | 0.5113 ±0.01 | 10.52 ±0.06 | 32.30 ±1.94 | 0.5067 ±0.00 | – |
| *C. longa* | – | – | – | 35.57 ±2.54 | 0.5114 ±0.00 | – | – | – | – | 45.40 ±1.96 | 0.5164 ±0.00 | 8.59 ±0.38 |
| *A. calamus* | 35.80 ±2.30 | 0.5038 ±0.00 | – | 35.33 ±4.11 | 0.4879 ±0.00 | – | 37.45 ±2.39 | 0.5019 ±0.01 | – | 38.87 ±2.67 | 0.5038 ±0.00 | – |
| *E. longifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| *G. glabra* | – | – | – | 44.33 ±2.51 | 0.5189 ±0.01 | 19.35 ±0.96 | – | – | – | – | – | – |

**Table 4.9** Hardness, weight and disintegration time of herbal tablets prepared using different binders and 20% MCC compressed at 20,000 N (n = 6) (cont.)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Leaf** | | | | | | | | | | | | |
| *C. angustifolia* | 20.48 ±2.12 | 0.4933 ±0.00 | – | 18.48 ±0.30 | 0.4974 ±0.00 | – | 13.38 ±1.22 | 0.5143 ±0.01 | – | 15.00 ±0.55 | 0.5002 ±0.00 | – |
| *A. paniculata* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. asiatica* | 34.65 ±3.50 | 0.5123 ±0.01 | – | 43.63 ±2.18 | 0.4967 ±0.00 | 12.10 ±0.06 | 24.67 ±1.74 | 0.5110 ±0.01 | – | 34.63 ±1.51 | 0.5066 ±0.00 | – |
| *P. indica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. hystrix* | 43.03 ±5.67 | 0.5092 ±0.00 | 5.55 ±0.54 | 43.67 ±1.22 | 0.5142 ±0.00 | 4.46 ±0.35 | 41.93 ±2.96 | 0.4868 ±0.01 | 7.01 ±0.46 | 51.50 ±3.13 | 0.5169 ±0.00 | 4.02 ±0.46 |
| **Stem** | | | | | | | | | | | | |
| *T. crispa* | 41.09 ±2.75 | 0.5078 ±0.00 | 10.10 ±0.54 | 41.50 ±1.91 | 0.5181 ±0.01 | 11.55 ±0.52 | 45.45 ±2.48 | 0.5092 ±0.01 | 20.55 ±0.51 | 41.79 ±3.61 | 0.5019 ±0.00 | 9.56 ±0.36 |
| *C. verum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. sappan* | – | – | – | – | – | – | – | – | – | – | – | – |
| *D. scandens* | – | – | – | – | – | – | – | – | – | – | – | – |

All values are expressed as mean ± SD, DT: Disintegration time

**4.5.5 Development Phase V** Effect of adding binder at a higher concentration

Adding binder at a higher concentration to a formulation could not be done directly by increasing the concentration of a binder in a granulating fluid, because the binding solution at a concentration of 10% is usually highly viscous. An indirect method by increasing the concentration of binder in this stage was performed by doing granulation twice. The granules prepared from the first granulation after drying were comminuted and subjected to the process of wet granulation again. The tablet hardness values of the formulation are shown in table 4.10.

**Formulation**

| | Amount per tablet (mg) |
|---|---|
| Herbal powder | 302.50 |
| Binder | 80.00 |
| Microcrystaline cellulose (MCC) | 100.00 |
| Talcum | 15.00 |
| Magnesium stearate | 2.50 |
| **Compression force** | 15,000 N |

Formulations that had the hardness of more than 40 N could not be successfully obtained (Table 4.10).

**Table 4.10** Hardness, weight and disintegration time of herbal tablets prepared using different binders by double wet granulation with 20% MCC and compressed at 15,000 N (n = 6)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Fruit** | | | | | | | | | | | | |
| *P. emblica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *S. trilobatum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *T. chebula* | – | – | – | – | – | – | – | – | – | – | – | – |
| *P. nigrum* | 21.87 ±2.05 | 0.5125 ±0.00 | – | 21.93 ±1.76 | 0.5088 ±0.00 | – | 18.67 ±1.48 | 0.5008 ±0.00 | – | 21.40 ±0.48 | 0.5047 ±0.01 | – |
| *M. citrifolia* | 19.47 ±2.19 | 0.5089 ±0.01 | – | 17.78 ±1.17 | 0.4974 ±0.01 | – | 20.20 ±2.99 | 0.5110 ±0.00 | – | 20.03 ±1.74 | 0.4975 ±0.00 | – |
| **Underground part** | | | | | | | | | | | | |
| *Z. officinale* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. longa* | – | – | – | – | – | – | – | – | – | – | – | – |
| *A. calamus* | 34.45 ±2.13 | 0.5100 ±0.01 | – | 32.58 ±1.56 | 0.5097 ±0.00 | – | 31.11 ±3.19 | 0.5119 ±0.00 | – | 30.78 ±0.91 | 0.5006 ±0.00 | – |
| *E. longifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| *G. glabra* | – | – | – | – | – | – | – | – | – | – | – | – |

**Table 4.10** Hardness, weight and disintegration time of herbal tablets prepared using different binders by double wet granulation with 20% MCC and compressed at 15,000 N (n = 6) (cont.)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Leaf** | | | | | | | | | | | | |
| *C. angustifolia* | 24.07 ±2.54 | 0.5085 ±0.00 | – | 21.13 ±1.33 | 0.4989 ±0.00 | – | 20.53 ±1.11 | 0.5124 ±0.00 | – | 23.60 ±1.89 | 0.4932 ±0.00 | – |
| *A. paniculata* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. asiatica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *P. indica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. hystrix* | – | – | – | – | – | – | – | – | – | – | – | – |
| **Stem** | | | | | | | | | | | | |
| *T. crispa* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. verum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. sappan* | – | – | – | – | – | – | – | – | – | – | – | – |
| *D. scandens* | – | – | – | – | – | – | – | – | – | – | – | – |

All values are expressed as mean ± SD, DT: Disintegration time

**4.5.6 Development Phase VI** Effect of adding binder at a higher concentration in combination with a compression force of 20,000 N

The formulations from the development phase V that had the hardness of more than 20 N but less than 40 N as shown in Table 4.10 were subjected to double wet granulation (the first batch of granules obtained were comminuted and reprocessed by wet granulation again) and compressed at 20,000 N. The summary of the formulation and the compaction condition was as follows:

**Formulation**

| | Amount per tablet (mg) |
|---|---|
| Herbal powder | 302.50 |
| Binder | 80.00 |
| Microcrystaline cellulose (MCC) | 100.00 |
| Talcum | 15.00 |
| Magnesium stearate | 2.50 |
| **Compression force** | 20,000 N |

From the results of development phases V and VI, addition of binder at a higher concentration into a formulation was not considered as an efficient method for improving the hardness of the herbal tablets (Table 4.11).

**Table 4.11** Hardness, weight and disintegration time of herbal tablets prepared using different binders by double wet granulation with 20% MCC and compressed at 20,000 N (n = 6)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Fruit** | | | | | | | | | | | | |
| *P. emblica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *S. trilobatum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *T. chebula* | – | – | – | – | – | – | – | – | – | – | – | – |
| *P. nigrum* | 27.70 ±2.37 | 0.4990 ±0.00 | – | 27.05 ±3.23 | 0.5130 ±0.00 | – | – | – | – | 27.20 ±1.42 | 0.5056 ±0.00 | – |
| *M. citrifolia* | – | – | – | – | – | – | 24.17 ±1.90 | 0.5089 ±0.00 | – | 23.83 ±2.29 | 0.4940 ±0.00 | – |
| **Underground part** | | | | | | | | | | | | |
| *Z. officinale* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. longa* | – | – | – | – | – | – | – | – | – | – | – | – |
| *A. calamus* | 37.10 ±2.77 | 0.4979 ±0.00 | – | 34.68 ±3.15 | 0.5017 ±0.01 | – | 36.58 ±2.24 | 0.5095 ±0.00 | – | 34.67 ±1.80 | 0.5155 ±0.01 | – |
| *E. longifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| *G. glabra* | – | – | – | – | – | – | – | – | – | – | – | – |

**Table 4.11** Hardness, weight and disintegration time of herbal tablets prepared using different binders by double wet granulation with 20% MCC and compressed at 20,000 N (n = 6) (cont.)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Leaf** | | | | | | | | | | | | |
| *C. angustifolia* | 25.15 ±0.65 | 0.5035 ±0.00 | – | 24.32 ±2.87 | 0.5090 ±0.01 | – | 24.45 ±1.63 | 0.5071 ±0.01 | – | 25.50 ±1.66 | 0.4906 ±0.00 | – |
| *A. paniculata* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. asiatica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *P. indica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. hystrix* | – | – | – | – | – | – | – | – | – | – | – | – |
| **Stem** | | | | | | | | | | | | |
| *T. crispa* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. verum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. sappan* | – | – | – | – | – | – | – | – | – | – | – | – |
| *D. scandens* | – | – | – | – | – | – | – | – | – | – | – | – |

All values are expressed as mean ± SD, DT: Disintegration time

**4.5.7 Development Phase VII** Effect of adding MCC at a concentration of 50%

The formulations of which the hardness values were less than 40 N from the development phase IV were further developed by increasing the concentration of MCC from 20% to 50%.

**Formulation**

| | Amount per tablet (mg) |
|---|---|
| Herbal powder | 179.50 |
| Binder | 53.00 |
| Microcrystaline cellulose (MCC) | 250.00 |
| Talcum | 15.00 |
| Magnesium stearate | 2.50 |
| **Compression force** | 15,000 N |

The results in Table 4.12 revealed that the tablet hardness values of the following formulations were greater than 40 N.

**Fruit**

*M. citrifolia*: SG(43.50±3.44 N) and PP(53.85±4.13 N)

A large number of formulations showed a significant increase in hardness with the values nearly met the acceptance criterion of 40 N. The remaining formulations were further investigated under the compression force of 20,000 N.

**Table 4.12** Hardness, weight and disintegration time of herbal tablets using different binders with 50% MCC compressed at 15,000 N (n = 6)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Fruit** | | | | | | | | | | | | |
| *P. emblica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *S. trilobatum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *T. chebula* | – | – | – | – | – | – | – | – | – | – | – | – |
| *P. nigrum* | 38.20 ±2.73 | 0.5063 ±0.00 | – | 37.78 ±1.80 | 0.5090 ±0.00 | – | 32.17 ±2.76 | 0.5103 ±0.01 | – | 28.37 ±1.53 | 0.5124 ±0.01 | – |
| *M. citrifolia* | 38.08 ±2.46 | 0.5019 ±0.01 | – | 43.50 ±3.44 | 0.5022 ±0.00 | 5.48 ±0.57 | 53.85 ±4.13 | 0.5029 ±0.01 | 15.47 ±0.60 | 32.23 ±0.00 | 0.4932 ±0.00 | – |
| **Underground part** | | | | | | | | | | | | |
| *Z. officinale* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. longa* | – | – | – | – | – | – | – | – | – | – | – | – |
| *A. calamus* | 38.49 ±2.12 | 0.5071 ±0.00 | – | 39.45 ±3.46 | 0.5092 ±0.01 | – | 39.18± 1.92 | 0.5154 ±0.00 | – | 37.56 ±1.15 | 0.5117 ±0.00 | – |
| *E. longifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| *G. glabra* | – | – | – | – | – | – | – | – | – | – | – | – |

**Table 4.12** Hardness, weight and disintegration time of herbal tablets using different binders with 50% MCC compressed at 15,000 N (n = 6) (cont.)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Leaf** | | | | | | | | | | | | |
| *C. angustifolia* | 36.30 ±2.72 | 0.5007 ±0.00 | – | 34.47 ±2.31 | 0.5055 ±0.01 | – | 34.38 ±1.94 | 0.5103 ±0.01 | – | 30.48 ±2.34 | 0.4976 ±0.00 | – |
| *A. paniculata* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. asiatica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *P. indica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. hystrix* | – | – | – | – | – | – | – | – | – | – | – | – |
| **Stem** | | | | | | | | | | | | |
| *T. crispa* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. verum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. sappan* | – | – | – | – | – | – | – | – | – | – | – | – |
| *D. scandens* | – | – | – | – | – | – | – | – | – | – | – | – |

All values are expressed as mean ± SD, DT: Disintegration time

**4.5.8 Development Phase VIII** Effect of adding MCC at a concentration of 50% together with a compression force of 20,000 N

The formulations which had unacceptable hardness from the development phase VII were further studied using a compression force of 20,000 N.

**Formulation**

| | Amount per tablet (mg) |
|---|---|
| Herbal powder | 179.50 |
| Binder | 53.00 |
| Microcrystaline cellulose (MCC) | 250.00 |
| Talcum | 15.00 |
| Magnesium stearate | 2.50 |
| **Compression force** | 20,000 N |

It was shown in Table 4.13 that almost all the remaining formulations from the development phase VIII had the hardness of more than 40 N as follows.

**Fruit**

*P. nigrum*: SP(43.67±1.11 N), SG(42.15±4.16 N) and PP(45.37±1.42 N)

**Underground part**

*A. calamus*: SP(43.18±1.35 N), SG(45.35±1.86 N), PP(45.65±2.33 N) and GT(41.83±1.42 N)

**Leaf**

*C. angustifolia*: SP(50.08±2.29 N), SG(46.20±3.65 N),PP(47.79±3.56 N) and GT(41.58±1.97 N)



Only the formulation of *P. nigrum* using gelatin solution as a binder had the average hardness slightly lower than 40 N (38.13±2.61 N). MCC proved to be the effective filler to enhance the tablet hardness although the high compression force was required to meet the qualified hardness.

**Table 4.13** Hardness, weight and disintegration time of herbal tablets using different binders with 50% MCC compressed at 20,000 N (n = 6)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Fruit** | | | | | | | | | | | | |
| *P. emblica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *S. trilobatum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *T. chebula* | – | – | – | – | – | – | – | – | – | – | – | – |
| *P. nigrum* | 43.67 ±1.11 | 0.5093 ±0.00 | 3.30 ±0.11 | 42.15 ±4.16 | 0.5155 ±0.00 | 2.08 ±0.06 | 45.37 ±1.44 | 0.5111 ±0.01 | 7.42 ±0.46 | 38.13 ±2.61 | 0.5115 ±0.00 | – |
| *M. citrifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| **Underground part** | | | | | | | | | | | | |
| *Z. officinale* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. longa* | – | – | – | – | – | – | – | – | – | – | – | – |
| *A. calamus* | 43.18 ±1.35 | 0.5042 ±0.00 | 8.11 ±0.06 | 45.35 ±1.86 | 0.5166 ±0.01 | 7.19 ±0.15 | 45.65 ±2.33 | 0.5026 ±0.00 | 8.32 ±0.39 | 41.83 ±1.42 | 0.4913 ±0.01 | 7.05 ±0.42 |
| *E. longifolia* | – | – | – | – | – | – | – | – | – | – | – | – |
| *G. glabra* | – | – | – | – | – | – | – | – | – | – | – | – |

**Table 4.13** Hardness, weight and disintegration time of herbal tablets using different binders with 50% MCC compressed at 20,000 N (n = 6) (cont.)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Leaf** | | | | | | | | | | | | |
| *C. angustifolia* | 50.08 ±2.29 | 0.5065 ±0.00 | > 1 hour | 46.20 ±3.65 | 0.5146 ±0.00 | > 1 hour | 47.79 ±3.56 | 0.5232 ±0.00 | > 1 hour | 41.58 ±1.97 | 0.4995 ±0.00 | > 1 hour |
| *A. paniculata* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. asiatica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *P. indica* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. hystrix* | – | – | – | – | – | – | – | – | – | – | – | – |
| **Stem** | | | | | | | | | | | | |
| *T. crispa* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. verum* | – | – | – | – | – | – | – | – | – | – | – | – |
| *C. sappan* | – | – | – | – | – | – | – | – | – | – | – | – |
| *D. scandens* | – | – | – | – | – | – | – | – | – | – | – | – |

All values are expressed as mean ± SD, DT: Disintegration time

**4.5.9 Development Phase IX** Effect of adding superdisintegrant

From disintegration results (Table 4.6-4.13), all formulations except *C. angustifolia* leaf tablet showed the disintegration time of less than the defined standard values (not more than 30 minutes). The superdisintegrant i.e. croscarmellose sodium (CS) at a concentration of 3% was added to improve disintegrating property. The formulation was as follows:

**Formulation**

| | Amount per tablet (mg) |
|---|---|
| *C. angustifolia* leaf powder | 179.50 |
| Binder | 53.00 |
| Microcrystaline cellulose (MCC) | 235.00 |
| Croscarmellose sodium (CS) | 15.00 |
| Talcum | 15.00 |
| Magnesium stearate | 2.50 |
| **Compression force** | 20,000 N |

It was shown in Table 4.14 that the formulation of *C. angustifolia* leaf tablet using SP or SG as a binder had the disintegration time of less than 30 minutes. The tablet hardness values were more than 40 N;

SP(44.85±5.89) and SG(50.55±1.63)

After the acceptable formulations were established, the scale-up batch (100 g) was produced. The tabletting machine was set to run continuously. The acquired tablets were investigated for the finished product quality control.

**Table 4.14** Hardness, weight and disintegration time of *C. angustifolia* tablets using different binders with 47% MCC and 3% CS compressed at 20,000 N (n = 6)

| Plant Types | SP | | | SG | | | PP | | | GT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) | Hardness (N) | Weight (g) | DT (min) |
| **Leaf** | | | | | | | | | | | | |
| *C. angustifolia* | 44.85 ±5.89 | 0.5033 ±0.01 | 22.02 ±0.76 | 50.55 ±1.63 | 0.4975 ±0.00 | 24.45 ±1.15 | 42.67 ±4.40 | 0.5054 ±0.02 | > 30 min | 54.08 ±3.30 | 0.4927 ±0.01 | > 30 min |

All values are expressed as mean ± SD, DT: Disintegration time

**4.6 Quality control of herbal tablet formulation**

The thickness and diameter of each herbal tablet was within the range of ±5% of the mean value. Weight variation of herbal tablets was within the acceptable range of 475.00-525.00 mg (479.70-512.00 mg) for the formulations designded to have a tablet weight of 500 mg and was within the range of 380.00-420.00 mg (0.3953-0.4039 g) for the formulations designd to have a tablet weight of 400 mg which indicated the consistency of the amount of active compounds in herbal tablets. The hardness of the tablets was more than 40 N (40.19-85.92 N) while the friability was lower than 1% (-0.25-0.64%) and the disintegration time was less than 30 minutes (0.44-26.36 min)(Table 4.15). These findings indicated that herbal tablet formulations obtained in this study have a high potential for production in the pharmaceutical industry.

In conclusion, the most appropriate herbal tablet formulation of each plant considered based on the tablet hardness and disintegration time was suggested in Table 4.16.

**Table 4.15** Quality control of herbal tablet formulations

| Plant Types | Diameter (mm) | Thickness (mm) | Weight (g) | Hardness (N) | Friability (%) | Disintegration time (min) |
|---|---|---|---|---|---|---|
| **Fruit** | | | | | | |
| ***P. emblica*** | | | | | | |
| PP +MCC 20%+20,000 N | 12.93±0.02 | 3.14±0.07 | 0.4980±0.02 | 46.67±4.47 | –0.05±0.01 | 6.25±0.36 |
| ***S. trilobatum*** | | | | | | |
| SP+15,000 N | 12.93±0.01 | 3.97±0.04 | 0.5120±0.01 | 65.63±2.80 | –0.08±0.02 | 1.38±0.10 |
| GT+15,000 N | 12.94±0.01 | 4.03±0.05 | 0.4995±0.01 | 57.00±2.60 | –0.04±0.01 | 2.47±0.09 |
| ***T. chebula*** | | | | | | |
| PP+MCC 20%+15,000 N | 12.92±0.01 | 3.16±0.04 | 0.4943±0.01 | 40.19±5.43 | 0.19±0.07 | 10.36±0.65 |
| ***P. nigrum*** | | | | | | |
| SP+MCC 50%+20,000 N | 12.90±0.02 | 3.35±0.02 | 0.5003±0.01 | 37.58±6.24 | –0.03±0.01 | 3.00±0.42 |
| SG+MCC 50%+20,000 N | 12.90±0.01 | 3.40±0.04 | 0.4995±0.01 | 38.65±5.43 | –0.05±0.01 | 2.20±0.25 |
| PP+MCC 50%+20,000 N | 12.87±0.01 | 3.48±0.04 | 0.5061±0.02 | 50.17±4.87 | –0.09±0.02 | 8.01±0.61 |
| ***M. citrifolia*** | | | | | | |
| SG+MCC 50%+15,000 N | 12.94±0.01 | 3.53±0.04 | 0.4917±0.01 | 36.55±2.12 | 0.29±0.06 | 5.21±1.16 |
| PP+MCC 50%+15,000 N | 12.88±0.01 | 3.56±0.05 | 0.5009±0.01 | 45.95±7.37 | 0.21±0.03 | 15.54±0.06 |

**Table 4.15** Quality control of herbal tablet formulations(cont.)

| Plant Types | Diameter (mm) | Thickness (mm) | Weight (g) | Hardness (N) | Friability (%) | Disintegration time (min) |
|---|---|---|---|---|---|---|
| **Underground part** | | | | | | |
| ***Z. officinale*** | | | | | | |
| PP+MCC 20%+20,000 N | 12.88±0.02 | 3.31±0.06 | 0.4920±0.02 | 53.32±6.49 | –0.04±0.00 | 20.18±1.5 |
| ***C. longa*** | | | | | | |
| GT+MCC 20%+20,000 N | 12.88±0.01 | 3.32±0.02 | 0.4979±0.01 | 47.15±2.32 | –0.09±0.01 | 9.26±0.10 |
| ***A. calamus*** | | | | | | |
| SP+MCC 50%+20,000 N | 12.90±0.02 | 3.31±0.45 | 0.5034±0.01 | 37.90±4.13 | crack | – |
| SG+MCC 50%+20,000 N | 12.92±0.01 | 3.52±0.01 | 0.5010±0.01 | 42.73±3.09 | 0.02±0.00 | 7.32±0.46 |
| PP+MCC 50%+20,000 N | 12.90±0.01 | 3.65±0.04 | 0.4990±0.01 | 43.37±4.50 | 0.64±0.08 | 6.29±0.12 |
| GT+MCC 50%+20,000 N | 12.90±0.01 | 3.62±0.03 | 0.5060±0.01 | 33.32±3.67 | crack | – |
| ***E. longifolia*** | | | | | | |
| PP+15,000 N | 12.89±0.01 | 3.82±0.04 | 0.5018±0.02 | 50.83±3.25 | –0.09±0.02 | 9.16±0.57 |
| ***G. glabra*** | | | | | | |
| SG+MCC 20%+20,000 N | 12.89±0.02 | 3.42±0.07 | 0.5011±0.02 | 41.08±7.85 | –0.06±0.01 | 19.55±0.68 |

**Table 4.15** Quality control of herbal tablet formulations(cont.)

| Plant Types | Diameter (mm) | Thickness (mm) | Weight (g) | Hardness (N) | Friability (%) | Disintegration time (min) |
|---|---|---|---|---|---|---|
| **Leaf** | | | | | | |
| ***C. angustifolia*** | | | | | | |
| SP+MCC 47%+CS 3% | 12.87±0.01 | 3.29±0.03 | 0.4884±0.01 | 48.38±7.17 | 0.13±0.02 | 21.26±1.04 |
| SG+MCC 47%+CS 3% | 12.86±0.01 | 3.44±0.04 | 0.5031±0.01 | 51.20±3.20 | 0.09±0.03 | 26.36±1.80 |
| ***A. paniculata*** | | | | | | |
| SP+20,000 N | 12.94±0.01 | 3.45±0.02 | 0.4915±0.02 | 44.33±3.75 | 0.12±0.01 | 9.02±0.41 |
| SG+20,000 N | 12.96±0.01 | 3.42±0.03 | 0.4842±0.01 | 42.70±8.02 | 0.16±0.02 | 8.54±1.04 |
| ***C. asiatica*** | | | | | | |
| SG+MCC 20%+20,000 N | 12.90±0.01 | 3.30±0.03 | 0.4909±0.01 | 43.58±7.14 | 0.10±0.02 | 13.48±1.54 |
| ***P. indica*** | | | | | | |
| SP+MCC 20%+15,000 N | 12.99±0.00 | 3.78±0.03 | 0.5006±0.01 | 32.35±4.53 | 0.09±0.02 | 3.43±0.59 |
| SG+MCC 20%+15,000 N | 12.97±0.01 | 3.73±0.05 | 0.5020±0.02 | 36.93±4.08 | –0.01±0.00 | 3.13±0.20 |
| PP+MCC 20%+15,000 N | 12.93±0.01 | 3.54±0.05 | 0.4797±0.08 | 38.78±3.76 | –0.01±0.00 | 6.43±0.66 |
| GT+MCC 20%+15,000 N | 12.94±0.01 | 3.90±0.05 | 0.5079±0.02 | 43.03±5.58 | –0.11±0.03 | 5.38±0.46 |
| ***C. hystrix*** | | | | | | |
| SP+MCC 20%+20,000 N | 12.96±0.01 | 3.68±0.06 | 0.5107±0.01 | 42.87±5.55 | –0.07±0.10 | 6.44±0.73 |
| SG+MCC 20%+20,000 N | 12.95±0.00 | 3.76±0.03 | 0.5096±0.01 | 49.18±4.07 | –0.03±0.02 | 5.43±0.46 |
| PP+MCC 20%+20,000 N | 12.95±0.01 | 3.63±0.05 | 0.4971±0.01 | 52.12±3.24 | –0.14±0.04 | 11.48±0.65 |
| GT+MCC 20%+20,000 N | 12.95±0.01 | 3.66±0.05 | 0.5019±0.02 | 44.65±5.25 | –0.03±0.00 | 10.19±0.90 |

**Table 4.15** Quality control of herbal tablet formulations(cont.)

| Plant Types | Diameter (mm) | Thickness (mm) | Weight (g) | Hardness (N) | Friability (%) | Disintegration time (min) |
|---|---|---|---|---|---|---|
| **Stem** | | | | | | |
| ***T. crispa*** | | | | | | |
| SP+MCC 20%+20,000 N | 12.95±0.01 | 3.53±0.04 | 0.5008±0.01 | 42.55±5.16 | 0.07±0.02 | 8.23±0.11 |
| SG+MCC 20%+20,000 N | 12.95±0.01 | 3.37±0.06 | 0.4973±0.01 | 41.87±5.76 | 0.25±0.05 | 9.41±0.35 |
| PP+MCC 20%+20,000 N | 12.95±0.01 | 3.59±0.06 | 0.5095±0.01 | 47.18±8.02 | 0.11±0.03 | 17.40±0.46 |
| GT+MCC 20%+20,000 N | 12.95±0.01 | 3.53±0.08 | 0.5043±0.01 | 38.60±3.88 | 0.13±0.02 | 12.05±1.16 |
| ***C. verum*** | | | | | | |
| SP+15,000 N | 12.92±0.02 | 3.54±0.05 | 0.5043±0.01 | 34.95±5.15 | crack | – |
| SG+15,000 N | 12.92±0.01 | 3.92±0.06 | 0.5119±0.01 | 34.52±4.78 | 0.07±0.06 | 3.55±0.42 |
| PP+15,000 N | 12.90±0.02 | 3.78±0.07 | 0.5060±0.01 | 46.78±6.83 | –0.03±0.00 | 4.17±0.28 |
| GT+15,000 N | 12.92±0.02 | 3.72±0.07 | 0.5021±0.01 | 54.30±4.28 | 0.05±0.01 | 9.43±0.48 |
| ***C. sappan*** | | | | | | |
| SG+15,000 N(400 mg) | 12.89±0.01 | 3.28±0.04 | 0.4039±0.01 | 55.02±3.81 | 0.12±0.05 | 0.44±0.30 |
| PP+15,000 N | 12.90±0.01 | 3.99±0.10 | 0.4929±0.02 | 41.43±7.58 | –0.25±0.04 | 3.35±0.51 |
| GT+15,000 N(400 mg) | 12.88±0.01 | 3.29±0.04 | 0.4065±0.01 | 50.80±6.34 | 0.12±0.01 | 0.54±0.32 |
| ***D. scandens*** | | | | | | |
| SP+15,000 N | 12.91±0.01 | 3.87±0.07 | 0.5067±0.01 | 67.42±6.53 | 0.03±0.02 | 8.32±0.43 |
| PP+15,000 N(400 mg) | 12.92±0.01 | 3.19±0.08 | 0.3953±0.02 | 48.43±6.66 | –0.04±0.01 | 12.44±2.33 |
| GT+15,000 N | 12.90±0.02 | 3.74±0.06 | 0.4900±0.01 | 85.92±7.34 | 0.10±0.05 | 8.31±0.98 |

All values are expressed as mean ± SD

**Table 4.16** Optimal herbal tablet formulations that passed quality control evaluation

| Plant Types | Formulation (Amount per tablet) | | | | | | Compression Force (N) |
|---|---|---|---|---|---|---|---|
| | Herbal powder (mg) | Binder (mg) | MCC (mg) | CS (mg) | Talcum (mg) | Mg Stearate (mg) | |
| **Fruit** | | | | | | | |
| *P. emblica* | 342.50 | 40 mg of PP | 100.00 | - | 15.00 | 2.5 | 20,000 |
| *S. trilobatum* | 432.50 | 50 mg of SP | - | - | 15.00 | 2.5 | 15,000 |
| *T. chebula* | 332.50 | 50 mg of PP | 100.00 | - | 15.00 | 2.5 | 15,000 |
| *P. nigrum* | 182.50 | 50 mg of PP | 250.00 | - | 15.00 | 2.5 | 20,000 |
| *M. citrifolia* | 182.50 | 50 mg of PP | 250.00 | - | 15.00 | 2.5 | 15,000 |
| **Underground part** | | | | | | | |
| *Z. officinale* | 342.50 | 40 mg of PP | 100.00 | - | 15.00 | 2.5 | 20,000 |
| *C. longa* | 322.50 | 60 mg of GT | 100.00 | - | 15.00 | 2.5 | 20,000 |
| *A. calamus* | 182.50 | 50 mg of PP | 250.00 | - | 15.00 | 2.5 | 20,000 |
| *E. longifolia* | 432.50 | 50 mg of PP | - | - | 15.00 | 2.5 | 15,000 |
| *G. glabra* | 332.50 | 50 mg of SG | 100.00 | - | 15.00 | 2.5 | 20,000 |

**Table 4.16** Optimal herbal tablet formulations that passed quality control evaluation (cont.)

| Plant Types | Formulation (Amount per tablet) | | | | | | Compression Force (N) |
|---|---|---|---|---|---|---|---|
| | Herbal powder (mg) | Binder (mg) | MCC (mg) | CS (mg) | Talcum (mg) | Mg Stearate (mg) | |
| **Leaf** | | | | | | | |
| *C. angustifolia* | 172.50 | 60 mg of SP | 235.00 | 15.00 | 15.00 | 2.5 | 20,000 |
| *A. paniculata* | 432.50 | 50 mg of SG | - | - | 15.00 | 2.5 | 20,000 |
| *C. asiatica* | 312.50 | 70 mg of SG | 100.00 | - | 15.00 | 2.5 | 20,000 |
| *P. indica* | 302.50 | 80 mg of GT | 100.00 | - | 15.00 | 2.5 | 15,000 |
| *C. hystrix* | 302.50 | 80 mg of SG | 100.00 | - | 15.00 | 2.5 | 20,000 |
| **Stem** | | | | | | | |
| *T. crispa* | 322.50 | 60 mg of SP | 100.00 | - | 15.00 | 2.5 | 20,000 |
| *C. verum* | 442.50 | 40 mg of PP | - | - | 15.00 | 2.5 | 15,000 |
| *C. sappan* | 342.50 | 40 mg of SG | - | - | 15.00 | 2.5 | 15,000 |
| *D. scandens* | 452.50 | 30 mg of GT | - | - | 15.00 | 2.5 | 15,000 |



**Tablet appearance**

The appearance of the optimal herbal tablet formulations that passed the quality control evaluation were shown in Fig 4.27-4.30. Herbal tablets manufactured from a single stroke tableting machine by continuous compression showed good

appearance. The formulations containing high concentration of MCC were lighter in color but seemed to have less homogeneity in color.

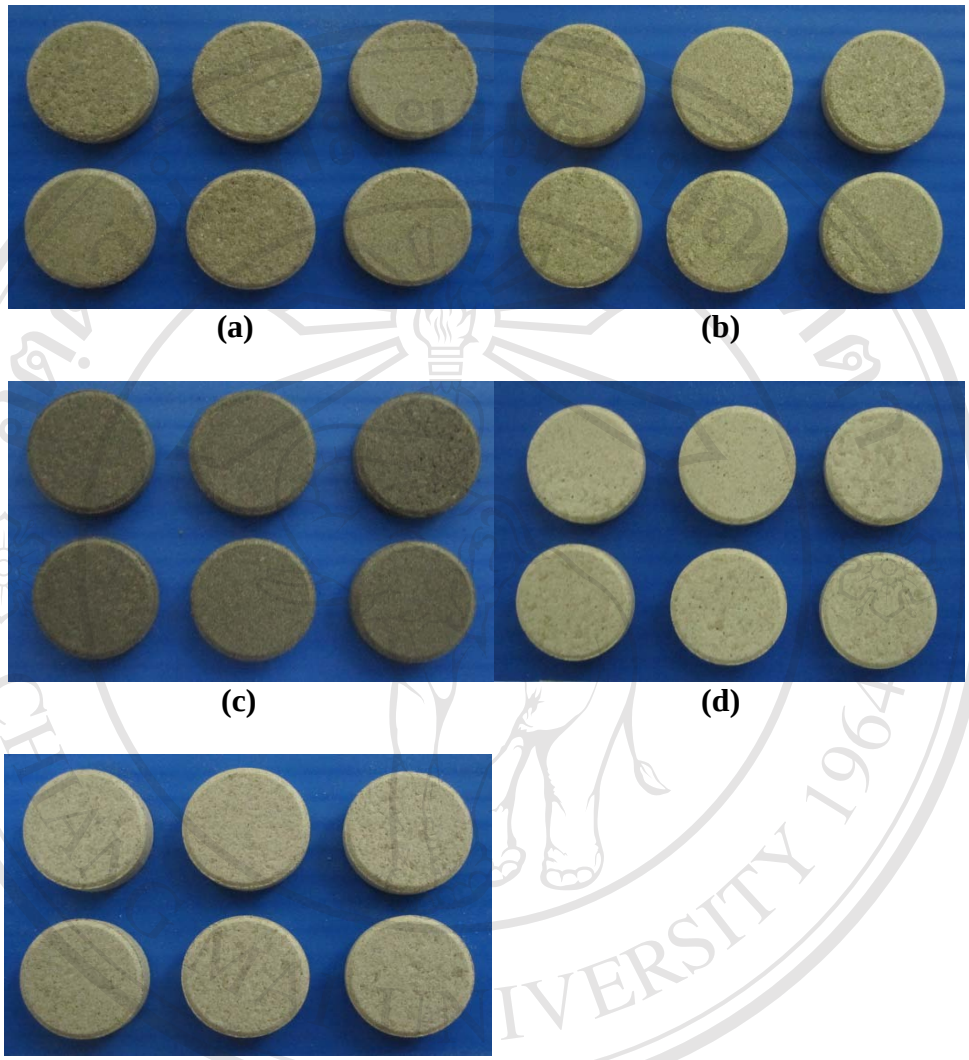



**Fig 4.27** Appearance of the most appropriate herbal tablet formulations from fruit powder:

(a) *P. emblica* PP+MCC 20%+20,000 N

(b) *S. trilobatum* SP+15,000 N

(c) *T. chebula* PP+MCC 20%+15,000 N

(d) *P. nigrum* PP+MCC 50%+20,000 N

(e) *M. citrifolia* PP+MCC 50%+15,000 N

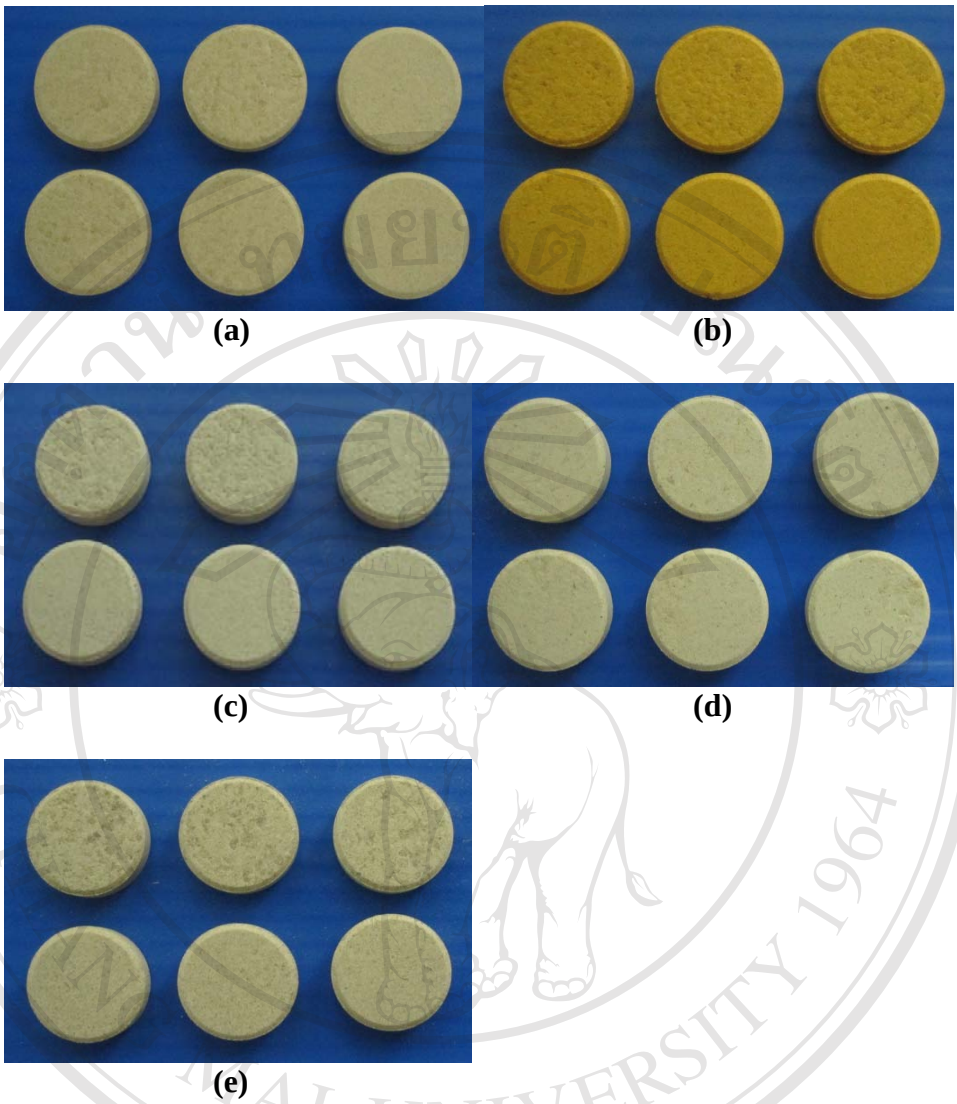



**Fig 4.28** Appearance of the most appropriate herbal tablet formulations from underground part powder:

(a) *Z. officinale* PP+MCC 20%+20,000 N

(b) *C. longa* GT+MCC 20%+20,000 N

(c) *A. calamus* PP+MCC 50%+20,000 N

(d) *E. longifolia* PP+15,000 N

(e) *G. glabra* SG+MCC 20%+20,000 N

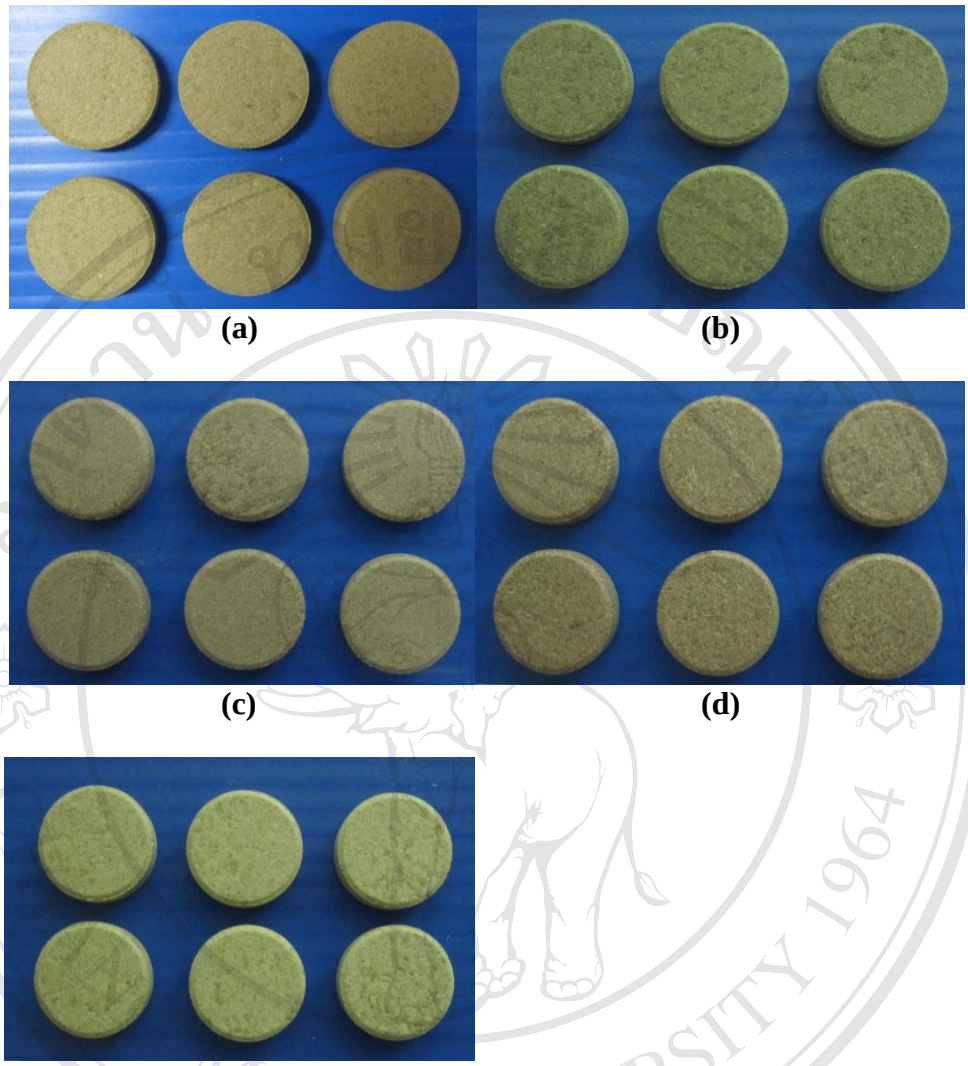



**Fig 4.29** Appearance of the most appropriate herbal tablet formulations from leaf powder:

(a) *C. angustifolia* SP+MCC 47%+CS 3%

(b) *A. paniculata* SG+20,000 N

(c) *C. asiatica* SG+MCC 20%+20,000 N

(d) *P. indica* GT+MCC 20%+15,000 N

(e) *C. hystrix* SG+MCC 20%+20,000 N

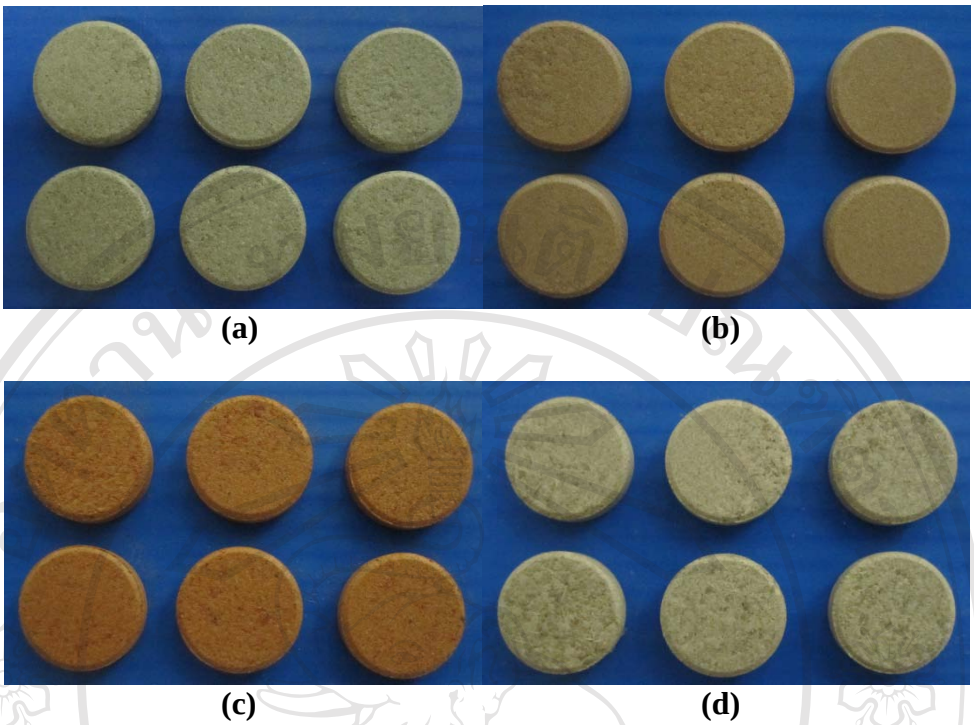



**Fig 4.30** Appearance of the most appropriate herbal tablet formulations from stem powder:

(a) *T. crispa* SP+MCC 20%+20,000 N

(b) *C. verum* PP+15,000 N

(c) *C. sappan* SG+15,000 N

(d) *D. scandens* GT+15,000 N