

Full length article

Investigation the Arithmetical or Tabular Islamic calendar

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ABSTRACT

Arithmetical calendar (or tabular calendar) is sometimes referred to as the Fātimid calendar but this is in fact one of several almost identical tabular Islamic calendars. This calendar introduced by Muslim astronomers in the 9th century CE to predict the approximate begin of the months in the Islamic lunar calendar. Chronologists adopted 11 leap years in a 30 year cycle. In the case of leap Hijri year they add one day to the last month of the Hijri year. The cycle of this calendar agree with the Smaller cycles (2–5.333 years) discovered by Galal and Rashed (2011) and coincide with the lag criterion given by Galal (1988).

We suggested the Islamic tabular calendar. The Leap years of this suggested Islamic tabular calendar may be 2, 5, 7, 10, 13, 15, 18, 21, 23, 26 and 29. Our suggested Arithmetical calendar satisfies the mathematical patterns, while the old Arithmetical calendar (or tabular calendar) does not satisfy a known fixed rule.

We conclude empirical formula for our suggested Islamic tabular calendar. From this empirical formula, we can calculate if the Hijric year after immigration is a leap or a non-leap year.

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1. Introduction

Many societies have used the lunar phase's cycle as the basis for their calendars. Even today a variety of cultures, including the 22% of the world population that holds the Islamic faith still begin their months with the first sighting of the crescent Moon in the evening after a New Moon. Therefore the Islamic calendar is a strict lunar calendar. Because the beginning of the Hijric month is determined by observation, it cannot be accurately predicted. However, for secular use a tabular calendar is available to determine the beginning of the Hijric month by fixed rules.

Islamic calendar converter is based on the arithmetical calendar (or tabular calendar), introduced by Muslim astronomers in the 9th century CE to predict the approximate begin of the months in the Islamic lunar calendar, reasonably accurate arithmetic calendars

were in practice, which is still used in most of the Islamic countries.

The Islamic tabular calendar consists of 12 lunar months. A lunar month on average has 29.530589 days. Assuming it is 29.5 days, and the lunar civil months are set to have 30 and 29 days alternately, we get a common year $29.5 \times 12 = 354$ days. This is 0.367068 days less than $29.530589 \times 12 = 354.367068$ Since this is very close to $11/30 = 0.3666666...$, Chronologists suggest 11 leap months every 30 to adjust the Islamic calendar. The error is 4×10^{-4} day per 30 years. This error accumulates to a day in 2492 years (The Hijric calendar, Umesh Nair, April 6, 2009).

Chronologists have made a rule that each of the odd-numbered months comprises of 30 days while each of the even-numbered months comprises of 29 days, starting at sunset. That is, there are 11 leap years in a 30 year cycle. In the case of leap Hijri year, Chronologists added one day to the last month of the Hijri year, McPartlan (1996).

Some scholars suggested alternate leap year schemes. There are four different alternate leap year schemes. The suggested schemes described in Table 1 as follows.

2. Results and discussion

We note that the cycles of the leap and non-leap years of the Islamic tabular calendar agree with the smaller cycles (2–5.333

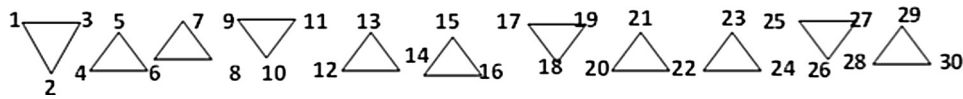


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Table 1

Leap years in each 30-year cycle and its usage.

Type	Leap years with 355 days in each 30-year cycle	Origin/usage
I	2, 5, 7, 10, 13, 15, 18, 21, 24, 26 & 29	Kuwaiti algorithm
II	2, 5, 7, 10, 13, 16, 18, 21, 24, 26 & 29	al-Fazāri, al-Khwārizmī, al-Battānī.(the most popular form)
III	2, 5, 8, 10, 13, 16, 19, 21, 24, 27 & 29	Fātimid calendar (also known as the Misri or Bohra calendar)
IV	2, 5, 8, 11, 13, 16, 19, 21, 24, 27 & 30	Habash al-Hāsib, al-Bīrūnī, Elias of Nisibis

**Fig. 1.** The suggested Arithmetical calendar after immigration.

years) discovered by Galal and Rashed (2011) and coincide with the lag criterion of the Moon after Sunset given by Galal (1988).

In the present study we suggest that the leap years of the Islamic tabular calendar after immigration may be 2, 5, 7, 10, 13, 15, 18, 21, 23, 26 and 29. Therefore the Arithmetical calendar pattern as in Fig. 1

According to Fig. 1 and Table 1, we can conclude the following consequences:

- (1) The old Arithmetical calendar (or tabular calendar) does not satisfy forms according to the particular system or particular rule.
- (2) Kuwaiti algorithm and popular calendar have a small variation from our suggested Arithmetical calendar. While Fatimid (Misri/Bohra) and al-Bīrūnī calendar have many variation from our suggested Arithmetical calendar.
- (3) Our suggested Arithmetical calendar satisfies the mathematical Pattern. In this mathematical pattern:
 - (i) The numbers of the first row of each a 30 year cycle is odd, while each number of the second row is even.
 - (ii) The heads of the triangles are leap years and its bases are non-leap years.

To know if a year after immigration leap year or non-leap year through our suggested Arithmetical calendar, we can conclude the following empirical formula:

- (1) If $H - \lfloor H/30 \rfloor \times 30$ belongs to (2, 5, 7, 10, 13, 15, 18, 21, 23, 26 and 29), then the year is a leap year.

where

H = the year after immigration i.e. the Hijric year.

$\lfloor H/30 \rfloor$ = the floor of $H/30$.

Examples:

- (1) To know if the year 1435 after immigration is a leap or a non-leap year, As follows:

$1435 - \lfloor 1435/30 \rfloor \times 30 = 1435 - (47 \times 30) = 25$,
Therefore the year 1435 is a non-leap year.

3. Conclusions

We can conclude that our suggested Arithmetical calendar satisfies the mathematical pattern while the old Arithmetical calendar (or tabular calendar) does not satisfy any fixed rule. We conclude empirical formula for the suggested Islamic tabular calendar. From this empirical formula, we can calculate if the Hijric year is a leap or a non-leap year. Also the cycle of our suggested Arithmetical calendar agree with the Smaller cycles (2–5.333 years) discovered by Galal and Rashed (2011) and coincide with the lag criterion given by Galal (1988).

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