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# ALKALOIDS FROM ROOTS OF *STRYCHNOS MATOPENSIS*

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**Key Word Index**—*Strychnos matopensis*; Loganiaceae; indole alkaloids; $^{13}C$ NMR.

**Abstract**—Twenty-six alkaloids have been identified in the root bark of *Strychnos matopensis* from Zaïre. They are Wieland–Gumlich aldehyde (WGA), desoxyWGA, *N*-formyldesoxyWGA, *nor*-*C*-fluorocurarine, *N*-desacetylretuline, *N*-desacetylisoretuline, isorosibiline, (16R)-isositsirikine, 11-methoxy diaboline, diaboline, matopensine, 16-methoxy isomatopensine, 16-ethoxy isomatopensine, 18-hydroxy matopensine, 18,18′-*bis*-hydroxy matopensine, matopensine *N*-oxide, strychnofuranine, bisnordihydrotoxiferine, bisnor-C-alkaloid H, bisnor-C-curarine, bisnor-C-alkaloid D, longicaudatine, longicaudatine F, longicaudatine Y, longicaudatine Z and *N*-oxylongicaudatine. The new compounds are *N*-formyldesoxy-Wieland–Gumlich aldehyde, the derivatives of matopensine, strychnofuranine and longicaudatine Z. Strychnofuranine is made up of two geissoschizal units with C-16 and C-17 being condensed into a furan ring.

## INTRODUCTION

*Strychnos matopensis* S. Moore is a climbing plant from eastern Africa [1]; it is the original source of a new type of toxiferine alkaloid named matopensine [2]. Study of the other alkaloids of the roots of this plant has revealed the presence of several matopensine-like compounds and of a wealth of monomeric and dimeric alkaloids. The purpose of this article is to give a full account of the structural analysis of these bases.

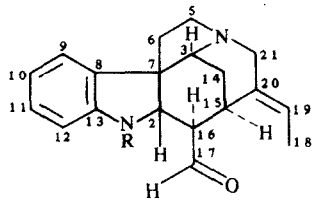
## RESULTS AND DISCUSSION

Alkaloids were displaced from their salts by means of concentrated ammonia and extracted with ethyl acetate; they were then separated from neutral compounds by extraction with aqueous sulphuric acid. Neutralization of the water phase and extraction with chloroform yielded the crude alkaloid mixture. From 1.2 kg of dried milled root bark was obtained 12.7 g of bases yield 10.2 g/kg), showing a myriad of spots on TLC. From this mixture 26 pure compounds were separated and fully identified. Their occurrence and characterization are summarized in Table 1.

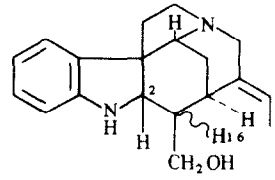
Wieland–Gumlich aldehyde **1** and desoxy Wieland–Gumlich aldehyde **2** are the most abundant monomers of the plant. These alkaloids are fairly common in African *Strychnos* species and while the former is found in *S. afzelii* [3], *S. dolychothyrsa* [4] and *S. longicaudata* [5], the latter has only been identified in the last two plants. Although being an hemiketal, compound **1** exists as a single diastereoisomer whose $^1H$ NMR spectra has been fully interpreted in connection with the recent analysis of the spectra of the alkaloids of *S. staudtii* [6].

Alkaloid **3**, *N*-formyl-18-desoxy-Wieland–Gumlich aldehyde, is the sole novel monomer from *S. matopensis*; its structure has been established on the basis of the following arguments. The mass spectrum of **3** shows a $[M]^+$ (*m/z* 322, $C_{20}H_{22}N_2O_2$) and a tryptamine fragment (*m/z* 172) 28 mass units above the corresponding ions of desoxy-Wieland–Gumlich aldehyde. The presence of a common base peak at *m/z* 164 featuring the iridoid moiety of the molecule suggests that the supplementary 28 mass units are present on the indole part of **3**. Comparison of the IR spectra of **2** and of **3** shows that this latter molecule does not possess a OH or a NH group; however, it displays a strong amide C=O vibration at 1665 $cm^{-1}$. Analysis of the 300 MHz $^1H$ NMR spectrum of **3** is complicated by the presence of signals for two rotamers in a 2 to 3 ratio. This spectrum shows signals for an aldehyde as a doublet at $\delta$ 9.75 ($J=4$ Hz) and as a singlet at $\delta$ 9.6. The presence of two other singlets at $\delta$ 8.85 and 8.6 suggests that a second carbonyl is present as a *N*-formyl group. This hypothesis is further supported by the observation of deshielded doublets for H-2 ($\delta=4.91$ and 4.74, $J=9$ Hz) and H-12 ($\delta=7.98$, $J=8$ Hz) and by comparison with the $^1H$ NMR spectrum of the related isoretulinal [7]. Final confirmation of the structure of **3** was obtained by $^{13}C$ NMR spectroscopy (Table 2) and by preparation of **3** from **2** and formic acid–acetic anhydride.

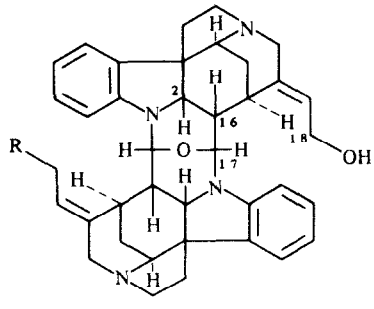
*N*-Desacetylretuline and *N*-desacetylisoretuline **5** and **6** are present as minor alkaloids in *S. matopensis*. Available hemisynthetic and natural authentic material, allowed in-detail investigation of the $^1H$ and $^{13}C$ NMR spectra of **5** and **6** in order to provide a safe data base for the assignments of the spectra of the related dimers. The proton spectra were assigned with the help of COSY-45 experiments in full agreement with the literature [8]. The carbon spectra were assigned by a carbon–proton correlation experiment through direct couplings and apparent proton decoupling [9]. The resolution obtained in the proton dimension was enough to allow unambiguous assignment of the protonated olefinic and aromatic carbons and of the C-5 and C-21 methylenes. In compound **5**, C-2 and C-3 which were 0.4 ppm apart were also



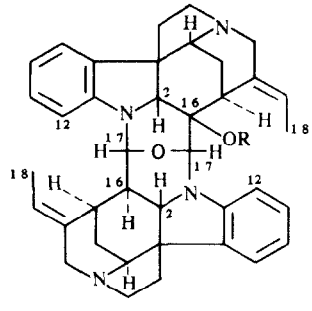
**2** R = H
**3** R = CHO
**27** R = COMe



**5** 16 $\beta$H
**6** 16 $\alpha$H



**14** R = H
**15** R = OH



**12** R = Me
**13** R = $C_2H_5$

Table 1. Occurrence and characterization of alkaloids from roots of *Strychnos matopensis*

| *Monomers* | Yield (%) | CCM | IR | UV | MS | $^1$H NMR | $^{13}$C NMR |
|---|---|---|---|---|---|---|---|
| Wieland-Gumlich aldehyde (WGA) **1** | 9 | + | + | + | + | + | |
| Desoxy-WGA **2** | 8 | + | + | + | + | + | |
| *N*-Formyldesoxy WGA **3** | <0.1 | + | + | + | + | + | |
| Nor-*C*-fluorocurarine **4** | 0.9 | + | + | + | + | + | |
| *N*-Desacetyl retuline **5** | ≤0.1 | + | + | + | + | + | + |
| *N*-Desacetyl isoretuline **6** | ≤0.1 | + | + | + | + | + | + |
| Isorosibiline **7** | <0.1 | + | + | + | + | + | |
| Isositsirikine **8** (16R) | 0.7 | + | + | + | + | + | |
| 11-methoxy diaboline **9** | 0.4 | + | + | + | + | + | |
| Diaboline **10** | 0.4 | + | + | + | + | + | |
| Dimers | | | | | | | |
| Matopensine **11** | 5 | | + | + | + | + | + |
| 16-methoxy isomatopensine **12** | 1.8 | | + | + | + | + | + |
| 16-ethoxy isomatopensine **13** | 0.2 | | + | + | + | + | |
| 18-hydroxy matopensine **14** | 0.8 | | + | + | + | + | + |
| 18,18′-bis. hydroxy matopensine **15** | 0.1 | | + | + | + | + | |
| Matopensine *N*-oxide **16** | 0.2 | | + | + | + | + | |
| Strychnofuranine **17** | 1 | | + | + | + | + | + |
| Bisnordihydrotoxiferine **18** | 0.5 | + | + | + | + | + | + |
| Bisnor-C-alkaloid H **19** | 0.3 | + | + | + | + | + | |
| Bisnor-C-curarine **20** | 2 | | + | + | + | + | + |
| Bisnor -C-alkaloid D **21** | 0.1 | | + | + | + | + | + |
| Longicaudatine **22** | 12 | + | + | + | + | + | |
| Longicaudatine F **23** | 0.1 | + | + | + | + | + | |
| Longicaudatine Y **24** | 0.3 | + | + | + | + | + | |
| Longicaudatine Z **25** | 0.1 | | + | + | + | + | + |
| *N*-Oxylongicaudatine **26** | 0.1 | | + | + | + | + | + |

Table 2. $^{13}$C NMR of alkaloids **3, 5, 6, 11, 12, 14, 18, 20, 21, 27**

| C | 5 | 6 | 27 | 3 | 18 | 20 | 11 | 14 | 12 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 64.0 | 71.7 | 67.2 | 64.4–64.2 | 72.1 | 95 | 62.9 | 62.8 62.8 | 68.5 76 | 74.5 |
| 3 | 64.4 | 61.8 | 61.8 | 61.9–61.8 | 67.9 | 68.6 | 65.4 | 65.3 65.1 | 65 61.2 | 63.8 |
| 5 | 53.6 | 53.3 | 54.1 | 54.0–53.6 | 54.8 | 55 | 53.8 | 53.6 54.1 | 53.2 53.2 | 53.7 |
| 6 | 38.8 | 42.3 | 43.9 | 44.5–43.2 | 42.4 | — | 37.3 | 37.3 37 | 45.5 43.1 | 49.1 |
| 7 | 53.4 | 53 | 50.8 | 52.5–52.0 | 54.0 | — | 53.5 | 53.4 53.3 | 53.5 54.1 | 52.2 |
| 8 | 135.3 | 134.4 | 138.1 | 137 | 137 | — | 133.9 | 133.8 133.8 | 136.7 135.5 | 135 |
| 9 | 122.0 | 121.4 | 122.7 | 122.3–123.1 | 122.7 | 122.7 | 122.7 | 122.7 112.7 | 122.2 122.3 | 122.6 |
| 10 | 119.2 | 119.0 | 124.7 | 125.6–125.5 | 116.2 | — | 117.2 | 117.9 118.1 | 119.9 119.8 | 120.1 |
| 11 | 127.8 | 127.6 | 128.0 | 129.5–129.3 | 128.1 | 128.4 | 128.2 | 128.6 128.3 | 128.6 127.4 | 128.9 |
| 12 | 109.6 | 109.8 | 115.6 | 117.7–110.5 | 106.9 | — | 103.8 | 103.9 104 | 112.6 104.7 | 110.1 |
| 13 | 150.1 | 148.9 | 140.2 | 139 | 145.9 | — | 146.5 | 146.4 146.3 | 148.5 152.4 | 148.5 |
| 14 | 22.9 | 27.9 | 27.4 | 27.3–29.2 | 24.3 | 23.3 | 23.3 | 23.5 23 | 23 32 | 28.4 |
| 15 | 28.6 | 28.6 | 30.3 | 30 –28.1 | 29.5 | 29.4 | 29.2 | 29.7 29.1 | 31.2 36.8 | 30.5 |
| 16 | 41.8 | 48.1 | 57.5 | 59.3–57.7 | 117.5 | — | 41.4 | 41.5 40.6 | 54 84.9 | 65.3 |
| 17 | 64.5 | 65.9 | 20.3 | 19.7–20.3 | 129.8 | 128.6 | 82.7 | 82.6 82.1 | 88.5 101.3 | 91.4 |
| 18 | 12.5 | 12.2 | 12.7 | 12.8–13 | 18.9 | 13.1 | 13.3 | 13.4 58 | 13.2 14 | 12.6 |
| 19 | 119.1 | 120.9 | 121.6 | 121.9–121.7 | 119.1 | 121.3 | 117.7 | 118 121.1 | 117.6 121.8 | 123.5 |
| 20 | 139.4 | 133.0 | 133.2 | 132 –133 | 140.5 | 140 | 141.5 | 140.6 145.1 | 139 132 | 137.4 |
| 21 | 52.9 | 57.6 | 58 | 57.4 | 52.6 | 51.4 | 52 | 51.9 51.6 | 55.7 61.0 | 56.4 |
| NCHO | | | | 160.8–158.0 | | | | | | |
| OMe | | | | | | | | | 55.4 | |
| N-Ac | | | 23.8 | | | | | | | |

Except in compounds **5** and **6** assignments of carbons with similar $\delta$ values and same multiplicity may be inverted. In compound **20** several resonances could not be distinguished from the noise.

distinguished owing to the non equivalence of their attached protons. These results, listed in Table 2, do not agree totally with published data [10]. In an analogous fashion, the $^{13}$C spectrum of isoretulinal **27** was interpreted and thence the spectrum of compound **3** was analysed.

Chemical shifts of the corresponding carbons in **5** and **6** show pronounced differences which may be related to the orientation of the 17-$CH_2OH$ substituent and also to ring E conformation (boat in desacetylretuline, chair in desacetylisoretuline) [8]. Although it might be hazardous to try to separate the two effects, it seems that the shielding of 14-$CH_2$ in **5** reflects a $\gamma$-interaction with the hydroxymethyl group and that the deshieldings of C-2, C-6, C-16 and C-21 in **6** are due to the more congested shape of the molecule ($\delta$-effects). Whatever the validity of these interpretations are, it also clearly appears from the chemical shifts of C-6, C-14 and C-21 that compounds **3** and **27** belong to the iso series.

Matopensine **11** was the first novel dimer isolated from *S. matopensis* and from *S. kasengaensis* [2, 7]. Its structure was deduced from the analysis of its spectra and from the measurement of H-2, H-16, H-15 coupling constants, it was deduced that matopensine belonged to the retuline series. The same conclusion can be deduced from the characteristic $^{13}$C chemical shifts of C-6, C-14, C-16 and C-21 (Table 2). Matopensine is accompanied by its mono *N*-oxide **16**, which is also present in *S. kasengaensis* [7].

Compound **12**, 16-methoxyisomatopensine, colours red upon Ce-IV spraying. Under electron impact, the mass spectrum shows an intense ion at *m/z* 568 (50%), which could not be analysed in a satisfactory fashion. Other important peaks are found in the low mass range (*m/z* 122, 130, 144, 168) and also in the vicinity of the $[M]^+$ (*m/z* 512 and 540). Fragmentation of this dimeric species into two halves was shown by peaks at *m/z* 277, 291, 307 and 308; some of these peaks are present in the fragmentation of strychnobilines [11]. From the IR spectrum of **12**, it could be deduced that no OH, NH or CO groups were present and the UV spectrum showed the chromophore to be of the indoline-type ($\lambda_{max}$: 217, 265 and 315 nm). The 300 MHz $^1$H NMR spectrum showed enough resonances to fit in a dimeric species and *inter alia* signals for eight aromatic protons and two ethylidene side chains (two broad quartets at $\delta$5.47 and 5.58 ppm and two double doublets at $\delta$ 1.86 and 1.89); it may be worth noting that the signals for these two similar groups have different lineshapes. As regards the structural elucidation of **12**, four signals were of importance: three singlets at 3.082 (3H), 4.568 (1H) and 4.736 (1H) and a doublet at 5.02 (1H, $J = 1.5$ Hz). Despite severe overlap in the high field region of the spectrum, several substructures were apparent, namely two $CH_2$–$CH_2$ units, two CH–$CH_2$–CH units and two $CH_2$–C=CH–Me units, which could be embodied into retuline moieties since no indole contribution was found in the UV spectrum. At this stage, it was felt that **12** might be an asymmetric matopensine derivative. Substitution of one of the H-16 is a means of breaking the symmetry of matopensine and of transforming H-2 and H-17 doublets into singlets at the observed locations.

The presence of an extra substituent was confirmed in part by the $^{13}$C NMR spectrum which showed a supplementary methoxy group at $\delta$ 55.4 (the 3.082 signal in the $^1$H NMR) and downfield shifts for one of the C-17 ($\delta$ +18.6) and C-2 (+13.1 ppm). As this hypothesis was not supported by the EI mass spectrum whose peak of highest mass (*m/z* 568) was lower than the $[M]^+$ of matopensine (*m/z* 570), a FAB spectrum of **12** was recorded. It showed

a quasi $[M]^+$ at $m/z$ 601, which corresponded to $C_{39}H_{44}N_4O_2$, suggesting therefore a 16-methoxymatopensine formula. In the part of the molecule which did not contain a methoxy group, H-2 appeared as a doublet with $J = 10.5$ Hz at $\delta = 4.01$ ppm instead of 5.5 Hz in matopensine; this feature is characteristic of the *iso* series. The presence of a substituted C-16 in the second half of the molecule did not allow such an assignment to be made on the basis of interproton couplings. The large lineshape differences of the $^1H$ signals of the two ethylidenes seemed to indicate that the two halves had different C-16 configurations. Curiously, 16-methoxy isomatopensine had a configuration similar to matopensine in the methoxylated part and different in the untouched (unsubstituted) moiety. This might mean that the mechanisms of formation of the 'matopensines' are flexible enough to tolerate all kinds of substitutions and configurations at C-16.

A tentative assignment of the $^{13}C$ NMR spectrum of **12** is given in Table 2. The observed chemical shifts are different from those of the corresponding monomers **5** and **6** and this can be justified by the presence of the supplementary oxazine rings and methoxy group. They also differ from the shifts observed in the parent matopensine **11** and an explanation may be found in the different configuration of the isoretuline part as well as in the overall different conformation of the molecule. The NOESY experiment provides information on this conformation and shows close spatial proximity between the H-2 on each moiety and also between H-17 and H-18 of one moiety and the aromatic H-12 of the other part.

Besides **12**, there was another 'red' alkaloid **13**, whose $^1H$ NMR spectrum also displayed two singlets at $\delta$ 4.72 and 4.86 ppm and a narrow doublet at 5.1 ppm. The EI mass spectrum of **13** showed a series of peaks, which also belonged to the spectrum of **12**, at $m/z$ 122, 130, 144, 158, 512, 540 and 568 (base peak). In the higher mass range, however, there were two ions with low intensity at $m/z$ 586 ($C_{39}H_{46}N_4O$) and 614 ($C_{40}H_{46}N_4O_2$). The $^1H$ NMR spectrum of **13** was interpreted by means of a COSY experiment and it showed signals for two moieties with the retuline skeleton. The only new correlations were found between two one-proton multiplets at $\delta$ 3.5 and 3.15 ppm and a three proton triplet at $\delta$ 1.1. These signals were assigned to those of an ethoxy group placed on one C-16 to account for the presence of the two above-mentioned singlets. The configurations of the two halves were as in compound **12**: isoretuline in the unsubstituted part and retuline in the ethoxylated part. The natural or artefactual origin of the ethoxy group may be debatable but it is difficult to imagine simple and reasonable elimination–addition mechanisms to account for the formation of **13** from **12**.

Compound **14** was also a 'red' alkaloid whose $^1H$ NMR spectrum presented several similarities with the spectrum of matopensine. Its mass spectrum displayed a $[M]^+$ at $m/z$ 586 ($C_{38}H_{42}N_4O$) and fragments at $m/z$ 569 $[M-OH]^+$, 568 $[M-H_2O]^+$ and 555 $[M-CH_2OH]^+$. Other typical peaks were observed at $m/z$ 122, 130, 144, 164, 165, 277, 279 and 293 arising from indole, ethyl piperidine and hydroxyethyl piperidine groups. The 300 MHz $^1H$ NMR spectrum of **14** showed signals for a single ethylidene chain and for hydroxyethylidene chain (one-proton triplet at $\delta$ 5.53 ppm and two-proton multiplet at $\delta$ 4.32), thus favouring the hypothesis of an 18-hydroxy substituted matopensine. Coupling constants between H-2, H-16 and H-17 were found similar to those exhibited by the corresponding protons of **11**, pointing to identical configurations. It is worth noting that substitution of one of the 18-methyls by a hydroxy shields the H-12 of the other moiety, thus showing the proximity of apparently distant protons. In the $^{13}C$ NMR spectrum, signals appear as pairs, which it is not possible to assign unambiguously.

Another 'red' compound with an unknown structure was **15**, a symmetrical dimer according to its $^1H$ NMR spectrum. Its $[M]^+$ was observed at $m/z$ 602 ($C_{38}H_{42}N_4O_3$); it was accompanied by fragments indicative of primary alcohol functions ($m/z$ 584 $[M-H_2O]^+$; $m/z$ 571 $[M-CH_2OH]^+$). The $^1H$ NMR spectrum of **15** and of matopensine had in common similar aromatic signals, a broad doublet at 5.5 (H-17), a doublet at 4.1 (H-2) and very similar high field regions. Absence of signals for an ethylidene chain and the presence of a one-proton triplet at $\delta$ 5.7 and of a two proton multiplet at 4.4 strongly suggest that **15** is a 18,18′-bis-hydroxy matopensine. Configurations of the asymmetric centres of **15** are as in the parent compound.

The matopensines were accompanied by three known alkaloids possessing the dihydrotoxiferine skeleton: bisnordihydrotoxiferine **18**, bisnor-C-alkaloid H **19** and bisnor-C-curarine **20**. This latter alkaloid has rarely been isolated from African *Strychnos* and to the best of our knowledge, it has only been found in minute quantities in *S. dolichothyrsa* [12]. $^{13}C$ NMR spectra of **18** and **20** are given in Table 2.

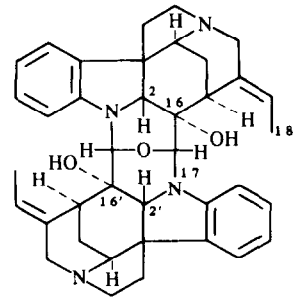
Alkaloid **21** was a symmetrical dimer, which we were first tempted to classify in the matopensine series after its red coloration with Ce-IV spray reagent. Its dimeric nature was deduced from mass spectral measurements, which showed ions in the 500 to 600 range; its symmetrical nature was apparent from the number of signals in the $^1H$ and $^{13}C$ NMR spectra. The mass spectrum of **21** showed the usual retuline fragments at $m/z$ 130, 144 (indole) and 121, 122 (ethyl piperidine) and a cluster of ions at $m/z$ 548, 550, 551, 552, 553, 554, 566 and 568. Analysis of the $^1H$ NMR spectrum of **21** by means of a COSY experiment allowed assignment of most of the protons of a retuline-type alkaloid. The key to the structural elucidation of **21** was the observation of two one-proton singlets at $\delta$ 4.95 and 4.55 which were assigned to H-17 and H-2, respectively. Upon standing in $CDCl_3$ solutions, compound **21** underwent chemical transformations and the $^1H$ NMR spectrum showed broadening of the high field resonances and increase of the number of singlets in the 4–5 area. Comparison of the $^1H$ NMR spectra of **21** and of known dimers showed a totally unprecedented shift for 18-Me ($\delta$ 0.58) [13–16].

Under the influence of the previous work on matopensines, it was first suggested that **21** was 16,16′-bishydroxymatopensine **28** and this was a reasonable explanation for the appearance of H-2 and H-17 as singlets. In the light of this hypothesis, molecular models were built and it was possible to fold the molecule in a manner such as to bring the C-18 methyl group on top of the aromatic rings. This hypothesis was not consistent however with the $^{13}C$ NMR spectrum (Table 2) and could not easily explain the chemical instability of **21**. In **21**, C-2 was *ca* $\delta$ 10 deshielded relative to the C-2 of matopensine; such a shift meant that the $\beta$-carbon atom (C-16) was substituted but functionalization by a heteroatom would be expected to induce a more important shift ($\delta$ 15). Substitution of C-16 was also apparent from its deshielding ($\delta$ 65.3) but this

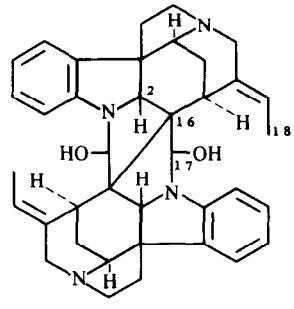
shift was not quite consistent with the required value for a tertiary carbon atom bearing an oxygen and flanked on each side by two heteroatoms (N-1 and O-17). For these reasons, the 16,16′-bishydroxymatopensine hypothesis was abandoned in favour of *bis*nor-C-alkaloid D: structure **21**. Remaining to be explained, was the chemical shift of the C-18 methyl group measured at $\delta$ 0.58 *vs* $\delta$ 2.23 in C-alkaloid D ($D_2O$, external TMS).

From the heroic literature on calabash curare alkaloids, it was known that tertiary bases such as caracurine V existed in the cyclic form **29** (13 rings) whereas in the corresponding quaternary series, toxiferine-I existed in the acyclic form **30** (11 rings) [17]. This observation meant that quaternization brought about conformational changes allowing $CH_2OH$ (C-18) to remain distant from the reactive C-17 atom; it also meant that the conformation of the *bis*tertiary base was such as to permit an easy cyclization of the $CH_2OH$ on C-17. The situation ought to be the same in the compounds with an extra 16–16′ bond since the bisnor derivative caracurine-II existed in the cyclic form **31** [15]. In the bisnor derivative of C-alkaloid D, **21**, the C-18 methyls are thus spatially close to the C-17 oxygens and this is the reason why the former is found at such a high field. There are precedents in the NMR literature of cage compounds for severe shieldings caused by alcohols [18]. Compound **21** had also been isolated in small quantities from *S. dolichothyrsa* and prepared by acid catalysed oxidation of bisnordihydrotoxiferine [12].

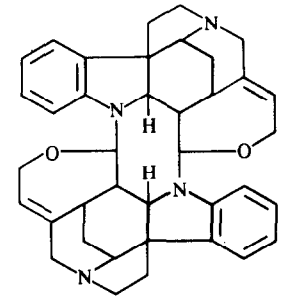
Four alkaloids displayed the blue colour of the longicaudatines upon Ce-IV spraying: longicaudatine **22**, longicaudatine F **23** and Y **24** and *N*-oxylongicaudatine **26**. The three longicaudatines **22**, **23** and **24** have been identified by direct comparison with samples isolated from *S. longicaudata* [5, 19]. The re-isolation of longicaudatine has allowed verification of the initial $^1H$ NMR assignments by means of a COSY experiment. In the $^{13}C$ NMR, direct and long-range proton to carbon correlations have brought a few modifications to the previous set of assignments (Table 3, ref. [19]). *N*-Oxylongicaudatine **26** was identified by its mass spectrum showing a weak $[M]^+$ at *m/z* 584 accompanied by a peak



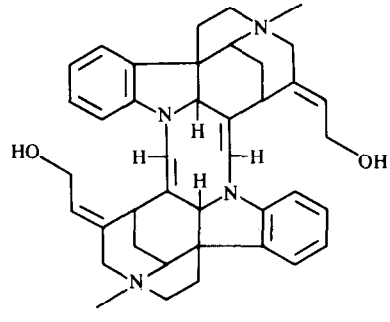
**28**



**21**



**29**



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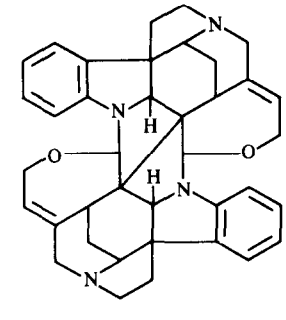


**31**

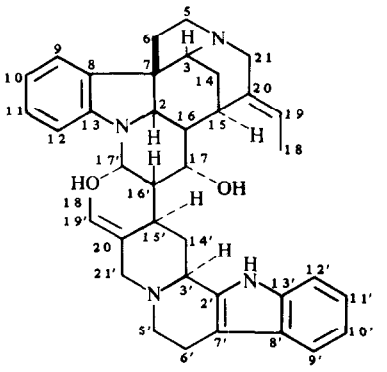
Table 3. $^{13}$C NMR of alkaloids **22**, **25**, **26** and **17**

| | Strychnane part | | | | Corynane part | | | |
|---|---|---|---|---|---|---|---|---|
| | **22** | **26** | **25** | | **22** | **26** | **25** | **17** |
| 2 | 60.5 | 59 | 63 | C-2′ | 132 | 132.7 | 133.3 | 134.6 134.8 |
| 3 | 59.9 | 81.4 | 58.2 | C-3′ | 54.7 | 54.2 | 50.3 | 55.9 58.6 |
| 5 | 51.4 | 68.3 | 51.3 | C-5′ | 50.6 | 52.1 | 52.1 | 51.9 52.6 |
| 6 | 39.9 | 36 | 36.6 | C-6′ | 18.3 | 18 | 20.6 | 21.2 21.6 |
| 7 | 51 | 50.6 | 50.7 | C-7′ | 108.1 | 107 | 107.7 | 108.3 108.5 |
| 8 | 136.9 | 136.2 | 136.8 | C-8′ | 127.8 | 128.5 | 126.9 | 127.4 128.4 |
| 9 | 122.6 | 122.8 | 122.7 | C-9′ | 117.9 | 118.1 | 118 | 118 118.1 |
| 10 | 119.4 | 120.2 | 119.2 | C-10′ | 118.9 | 118.9 | 119.8 | 119.3 119.3 |
| 11 | 128.1 | 129.3 | 129.1 | C-11′ | 119.1 | 122.5 | 121.4 | 121.3 121.4 |
| 12 | 108.5 | 109 | 107.3 | C-12′ | 110.5 | 109.9 | 110.7 | 108.6 110.7 |
| 13 | 147 | 145.9 | 150 | C-13′ | 135.6 | 133.2 | 133.2 | 136.2 136.2 |
| 14 | 27.1 | 24.9 | 20.8 | C-14′ | 31.4 | 31.7 | 34.7 | 33.1 37.7 |
| 15 | 32.2 | 30.5 | 30.7 | C-15′ | 38.6 | 38.2 | 39.5 | 34.1 36.1 |
| 16 | 42.7 | 42 | 45.6 | C-16′ | 116.5 | 117 | 45.5 | 122.1 155.5 |
| 17 | 82.6 | 82 | 63.8 | C-17′ | 127 | 126.7 | 67.1 | 137.6 110.7 |
| 18 | 64.9 | 64.2 | 12.8 | C-18′ | 13.1 | 12.9 | 13.4 | 12.6 13.6 |
| 19 | 129.8 | 126.7 | 125.9 | C-19′ | 124.5 | 120.8 | 122.9 | 122.8 121.9 |
| 20 | 132.5 | 134.2 | 136.0 | C-20′ | 134.3 | 132.7 | 133.3 | 134.2 133.3 |
| 21 | 53.2 | 70.7 | 51.8 | C-21′ | 55.4 | 55.0 | 51.8 | 60.7 64.0 |

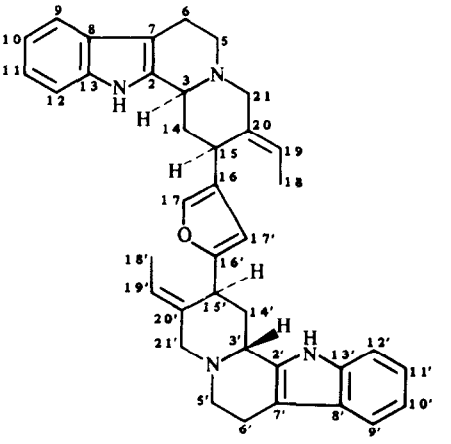
at *m/z* 568 $[M-16]^+$, 100%). The $^1$H NMR spectrum showed an exchangeable NH at $\delta$ 9.1 ppm, H-17′ singlet at 6.02 ppm and a deshielded H-19 triplet at $\delta$ 6.37 instead of 6.08 ppm in the parent compound [19]. This compound has previously been found in *S. chrysophylla* and this only reported chemical shift was used to locate the oxygen on the strychnane moiety of the molecule [20]. The same conclusion could be deduced from the $^{13}$C NMR spectrum of **26**, which exhibited resonances very close to those of **22**, with the exceptions of those of C-3 (81.4 ppm), C-5 (68.3 ppm) and C-21 (70.7 ppm) which were deshielded by the proximity of the *N*-oxide function (Table 3).

Although staining yellow upon Ce-IV spraying, the new alkaloid **25** was identified with a longicaudatine by its mass spectrum which showed the ethylidene indoloquinolizidine cluster of ions at *m/z* 249, 250, 251. There was no clear $[M]^+$ but one could observe ions at *m/z* 552, 553, 554 and 555, accompanied by small peaks at *m/z* 568, 570, 582, 584 and 586. At variance with the spectra of the other longicaudatines was the superimposition of indole (283, 291 nm) and indoline (225, 255, 310 nm) chromophores in the UV spectrum of **25**. The $^1$H NMR spectrum showed an exchangeable N–H ($\delta$ 8.03) and signals for two ethylidene chains (5.55 and 5.53, one-proton quartets; 1.65 and 1.75 ppm, three-proton doublets). Instead of the H-17′ singlet of the longicaudatines, the $^1$H NMR spectrum of **25** exhibited a doublet at $\delta$ 5.95 ($J = 3$ Hz), which coupled with a multiplet appearing at $\delta$ 2.3 (COSY spectrum). Assignment of the $^{13}$C spectrum of **25** allowed the structure of a 16′,17′-dihydro-17′-hydroxy-longicaudatine *Y* to be proposed for this compound. Two methine resonances at 67.1 and 63.8 ppm were assigned to the hydroxylated C-17′ and C-17. The relatively high field of these resonances may be due to 1–3 $\gamma$ interactions between the two OH groups. Observation of a small coupling between H-17′ and H-16′ (3 Hz) and of a long-range interaction between H-17′ and H-17 (evidenced by the COSY spectrum) allowed the depicted (17′*S*), (16′*S*), (17*S*) configuration with H-17 and H-17′ $\beta$ equatorial and H-16′$\beta$ axial. The values of the $^1$H and $^{13}$C chemical shifts and of the H-17′–H-16′ coupling constant are similar to those found in isoeburnamine [21].

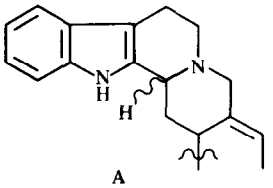
The last compound with an unknown structure **17** was an indole according to its UV spectrum. Its mass spectrum was dominated by the ions *m/z* 249, 250 and 251 of the ethylidene indoloquinolizidines and a $[M]^+$ was found at *m/z* 568 ($C_{38}H_{40}N_4O$); it was accompanied by a strong peak at $[M-1]^+$, also characteristic of the indoloquinolizidines. The $^1$H NMR spectrum showed two exchangeable NH groups ($\delta$ 7.89 and 7.80) and signals for two ethylidene side chains (two quartets at $\delta$ 5.61 and 5.48 and two three-proton doublets at 1.61 and 1.27 with $J = 7.2$ and 6.6 Hz). In the low field part of the spectrum, two broad singlets were observed at $\delta$ 7.184 and 6.043 ($W_{1/2} = 2$ Hz). This spectrum was analysed at 300 MHz by means of a COSY-45 experiment (Fig. 1). Several subsets of protons were thus detected: the readily assigned methyl on C-18 coupled to olefinic H-19 as well as to H-21. The H-21 of one of the moieties were found to be equivalent while in the other they were 0.3 ppm apart. In this latter half there was coupling between H-18 and H-15 while in the former this coupling was not detected; in both parts there was coupling between H-19 and H-15. Identification of two H-15 allowed localization of two $CH_2$-14 and thence two H-3 which were broad doublets appearing at 3.55 and 3.39 ppm. As in most indoloquinolizidines there was long-range coupling between H-3 and part of complex four-spin systems featuring the tryptamine protons ($2.5 < \delta < 3.2$ ppm). Vicinal and geminal couplings were distinguished according to the tilt of the correlations. These data allowed the identification of two ethylidene indoloquinolizidine systems such as A. The indole nuclei were considered to be unsubstituted owing to the absence of any simple signal in the aromatic protons area. The two units A accounted for a $C_{34}H_{38}N_4$ composition, thus



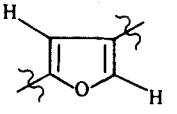
25



17



A



B

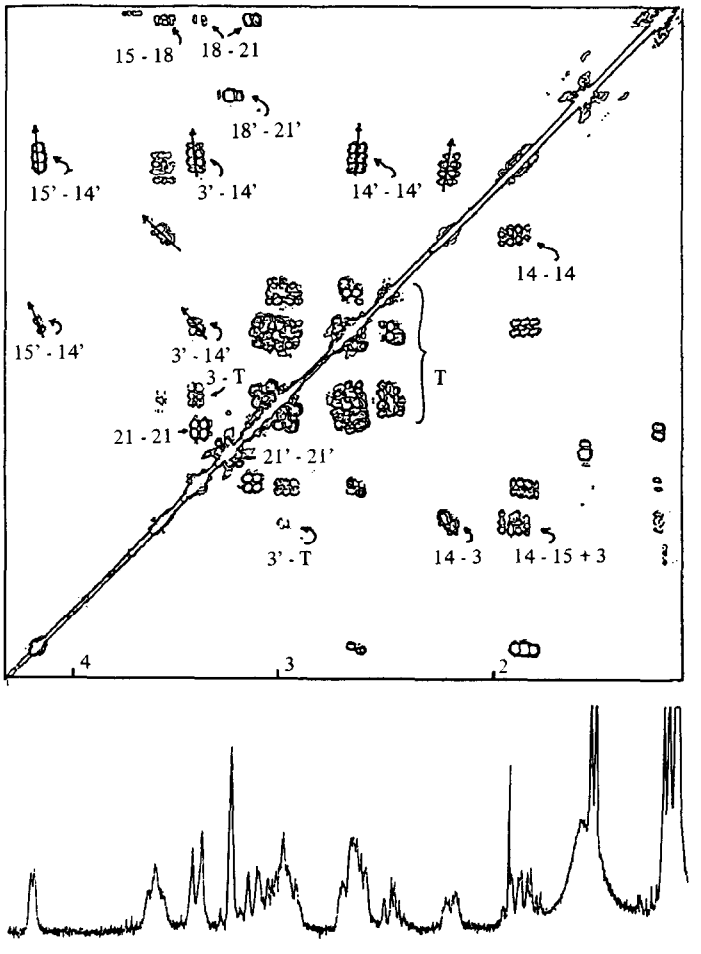



Fig. 1. COSY spectrum of **17**.

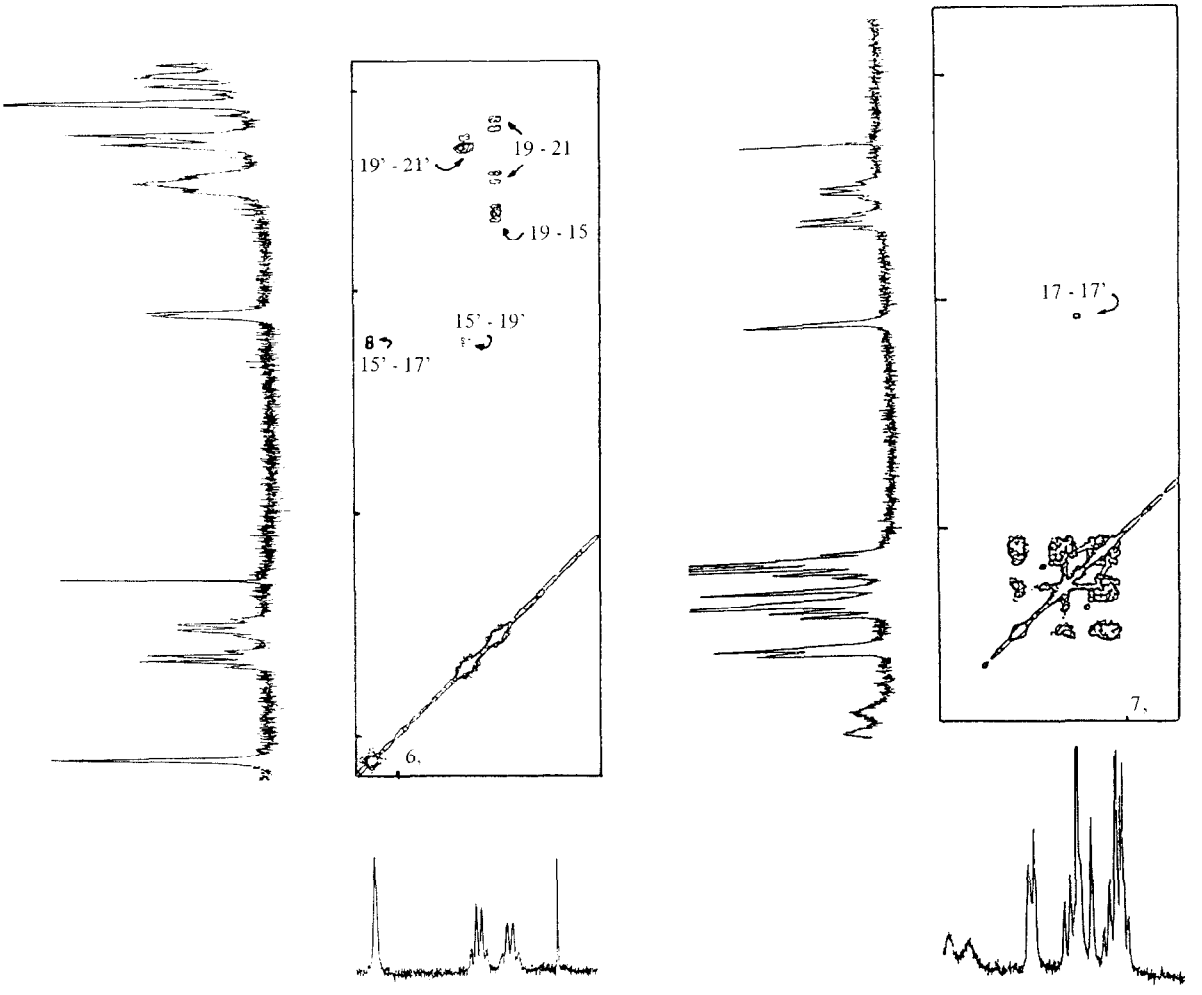



Fig. 1. (A and B).

leaving a $C_4H_2O$ segment to link the two $C_{17}$ fragments. In the absence of a carbonyl (IR spectrum), a 2,4-disubstituted furan such as B was proposed for the $C_4$ unit. The two above broad singlets are $\alpha$ and $\beta$ protons of the furan ring. The COSY spectrum (Fig. 2) showed that they were coupled and that one of them coupled also to one of the H-15. This led to structure **17** for this alkaloid, for which we propose the name of strychnofuranine: this proposal was supported by the $^{13}C$ NMR spectrum of **17**, which showed the correct number of signals with appropriate multiplicity (Table 3).

To complete the structural work, it remained to establish the configurations of C-3 and C-3', given the known 'biogenetic' configurations of C-15 and C-15', and also it remained to explain the different $\delta$ values of the protons and carbons of rings D and D'. From the IR spectra (Bohlmann bands) and from the chemical shifts of H-3' and H-3 (3.39 and 3.55 ppm) it appeared that the C/D and C'/D' ring junctions were *trans*. This was an unusual characteristic for 20-ethylidene indoloquinolizidines, which are *cis* in the 3$\alpha$-H series (geissospermine [22], geissoschizine [23]) and in the 3$\beta$-H series (rhazimanine [24], bhimberine [25]). To the best of our knowledge, there are, in the literature, two exceptions: *O*-methylgeissoschizine [23] and the $\Delta^{19}Z$ quasidimers of *S. dale* [26]. In the former case the unfavourable interaction between C-18 methyl and the C-15 substituent, is alleviated by distortion of the dihedral angle while in the latter case the C-18 methyl is simply displaced out of the field of interactions. To check the possibility of having a *Z* double bond, a NOESY experiment was performed (Fig. 2). Both moieties showed the H-21→H-19 transfers of magnetization indicative of *E* double bonds; the other important NOEs were observed between H-17' and H-21' and between H-18' and H-15'. There was no noticeable NOEs between H-18 and H-15 and H-17 and H-21 and, therefore, for this moiety, it was possible to propose the 3$\alpha$H configuration and C and D ring conformations of *O*-methylgeissoschizine as established by X-ray crystallography [27]. Protons H-3 and H-15 are axial in a chair-like ring D and the C-15 substituent (the furan ring) is in a plane perpendicular to the mean plane of ring D; in this fashion, interaction between the two rings are kept to a minimum. As regards the other moiety, the observation of a NOE between H-18' and H-15' and between H-17' and H-21' may be interpreted by a conformation in which the

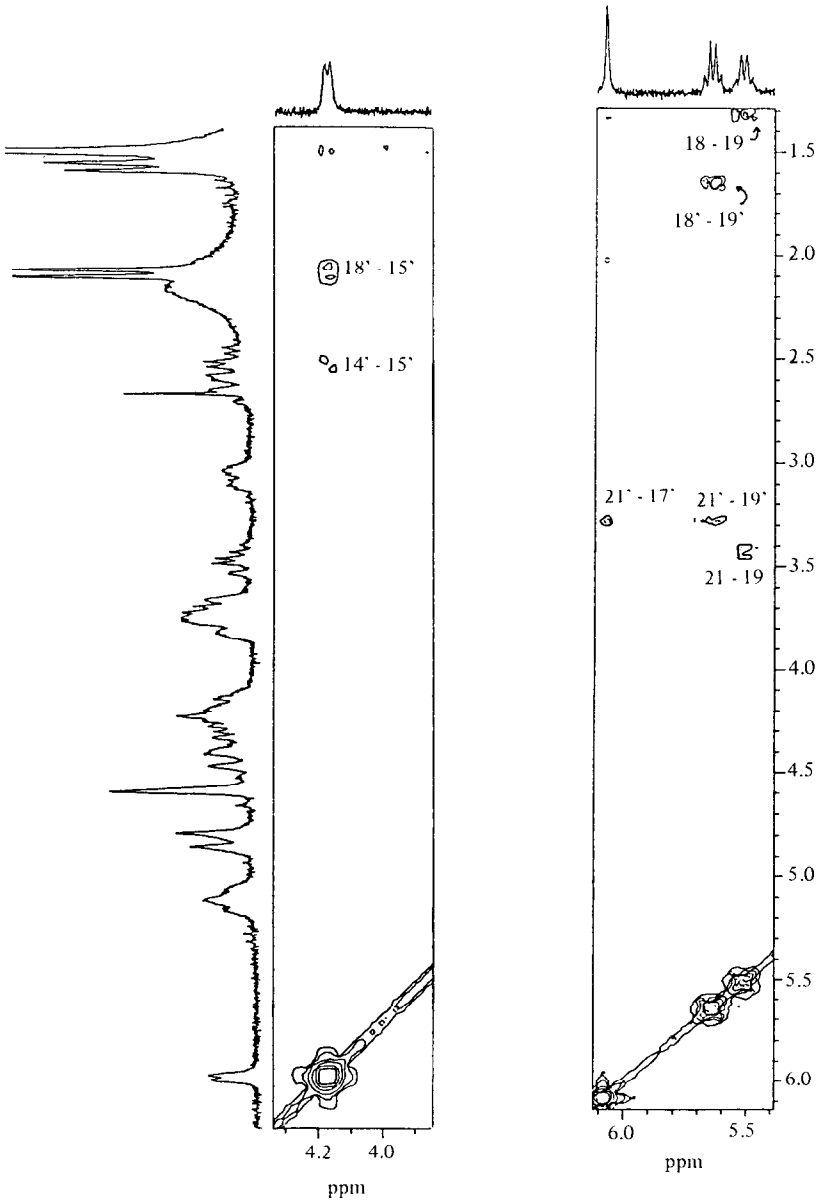



Fig. 2. NOESY spectrum of **17**.

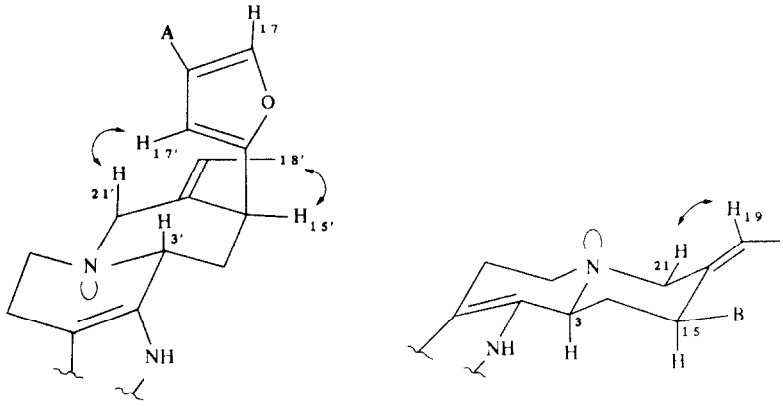
furan ring is axial and H-15 equatorial and close to H-18. Of the two possible configurations C (chair) and D (boat), the former only accounts for the H-17′ to H-21′ NOE. In this case the *trans*-quinolizidine junction is obtained for the 3′β-H configuration.

## CONCLUSION

The alkaloids of *S. matopensis* show all the possibilities offered by the coupling of aldehydes such as Wieland–Gumlich aldehyde, its desoxy counterpart and geissoschizal. The most frequently encountered 'dimers' belong to the curare type and are the toxiferines and also the matopensines. Cross-linking between the WGA-type monomers and geissoschizal yields the longicaudatines which were the major alkaloids of *S. longicaudata* of the same Penicillatae section. The isolation of strychnofuranine **17** in *S. matopensis* illustrates a novel means for coupling of geissoschizal. Although there is no simple chemical way of condensing two aldehydes into a 2,4-disubstituted furan, one can envisage a sequence involving crotonization, allylic oxidation, cyclization and aromatization (Scheme 1).

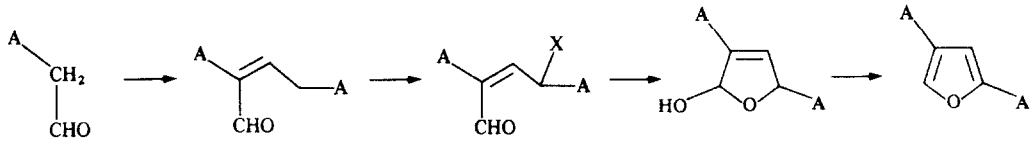
## EXPERIMENTAL

*General.* Plant material was collected by one of us (C.D.) in the Shaba area in Zaire, near the road between Mokambo and Tera. Collections were part of the 'Etude Phytochimique de flores Africaines' research project. Material was identified by H.



**17**

Scheme 1. Proposed conformations of the two halves of strychnofuranine. Arrows refer to observed NOEs.



Scheme 2. Possible mechanism of condensing two aldehydes to form a 2,4-disubstituted furan.

Breyne; a specimen is deposited in the herbarium of the Brussels National Gardens under No. HB 3743. $^1$H NMR were measured at 300 MHz, $^{13}$C NMR at 75 MHz. COSY spectra and $^1$H–$^{13}$C correlations were performed with the use of the Bruker library of microprograms. TLC solvents (silica gel) were $CH_2Cl_2$–MeOH–$NH_4OH$, (92:7:1) for frs 1–820 and (91:8:1) for frs 820–2020.

*Extraction.* Finely ground dried root bark (1.2 kg) was wetted with 750 ml of a 50% soln of conc. $NH_4OH$ and extracted overnight in 40 l of EtOAc. The organic soln was extracted with 2% $H_2SO_4$ until a Mayer's reagent test was negative, the acid layer sepd, made alkaline with $NH_4OH$ and extracted with $CHCl_3$. The $CHCl_3$ soln was washed with $H_2O$, dried ($Na_2SO_4$) and evapd *in vacuo* to give 12.7 of crude alkaloid mixt.

*Separation of alkaloids.* Alkaloid mixt (12.7 g) was fractionated on 1.5 kg of Merck silica gel H-60 (elution pressure 10 bar). Initial solvent was $CH_2Cl_2$ (4.5 l); it was followed by a gradient of MeOH in $CH_2Cl_2$, 99:1 (4 l), 49:1 (3 l), 19:1 (7 l), 9:1 (5 l), 4:1 (11.5 l), 1:1 (10 l) and MeOH (13.5 l); 30 ml fractions were collected. Strychnofuranine **17** was the major component of frs 651–723 (226 mg); it was the least polar constituent of those fractions which were eluted with $CH_2Cl_2$–MeOH (9:1). Isositsirikine **8** was eluted in frs 861–876 (213 mg); it was followed by several alkaloids of lower polarity: nor-C-fluorocurarine **4** in frs 877–884 (94 mg), *bis*nor-C-curarine **20** in frs 893–910 (184 mg), matopensine **11** (frs 921–945), *bis*nor-C-alkaloid D **21** (frs 921–945) and matopensine *N*-oxide **16**. Nordihydrotoxiferine **18** had the same $R_f$ value as matopensine but was eluted later in frs 979–997 (145 mg). Fractions 1003–1061 were mixts of desoxy-WGA **2**, 16-ethoxy isomatopensine **13** and longicaudatine **22** (total 400 mg); the order of elution from the column was **2**, then **13**, then **22**; the order of polarity on TLC was **13** (higher $R_f$), then **22**, then **2**. Fractions 1062–1190 were almost pure longicaudatine **22** (1 g); this alkaloid was present in all fractions, until fr. 1560. Fractions 1190 to 1300 were mixts of **22**, **2** and 18-hydroxy matopensine **14**; *N*-formyldesoxy-WGA **3** was in frs 1301–1344. Fractions 1361 to 1650 were complex mixts of *bis*nor-C-alkaloid H, **19**, 18,18′-*bis* hydroxy matopensine **15**, longicaudatine F, **23**, Y, **24** and Z, **25**; longicaudatine *N*-oxide **26**; diaboline **10** and 11-methoxydiaboline **9** (two alkaloids with the same polarity), isorosibiline **7**, *N*-desacetylretuline **5**, *N*-desacetylisoretuline **6** and 16-methoxyisomatopensine **12**. Approximate order of polarity on TLC was **12**, **22**, **19**, **24**, **5**, **6**, **9** + **10**, **25**, **7**, **16**, **15** (increasing polarity). WGA was eluted from the column with MeOH in frs 1721–2020.

*Hemi synthesis of* N-*formyldesoxy-WGA* **3**. Desoxy-WGA **2** (10 mg) from *S. matopensis* was dissolved in 0.3 ml of a 1:1 mixt of 40% aq $HCO_2H$ and $Ac_2O$. After 2 hr stirring, the reaction mixt was dild with $H_2O$, made alkaline with $NH_4OH$ and extd with $CHCl_3$. Usual treatment of the organic layer yielded 8 mg of a less polar compound with UV, IR, MS and 300 MHz $^1$H NMR spectra superimposable on those of the natural product.

N-*Formyl*-18-*desoxy-Wieland–Gumlich aldehyde* **3**. (CR pink); $[\alpha]_D$ +39° ($CHCl_3$, *c* 0.76); UV $\lambda_{max}^{MeOH}$ nm: 218, 253, 282, 290; IR $\nu_{max}^{CHCl_3}$ cm$^{-1}$: 2920, 2715, 1725, 1665, 1600, 1485, 1470, 1365, 760; MS *m/z* (rel. int.): 322[M]$^+$ (35), 294(20), 293(25), 279(90), 172(35), 164(100), 144(50), 136(30), 130(30), 122(50), 121(40), 108(50); $^1$H NMR (300 MHz, $CDCl_3$): 9.75 (*d*, *J* = 4 Hz, H-17), 9.6 (*s*, H-17), 8.85 (*s*, NCHO), 8.6 (*s*, NCHO), 7.98 (*d*, *J* = 8 Hz, H-12), 5.5 (2*q*, *J* = 7 Hz, H-19), 4.91 (*d*, *J* = 9.3 Hz, H-2), 4.74 (*d*, *J* = 9 Hz, H-2), 1.6 (*dd*, *J* = 2.1, 6.9 Hz, Me-18), 1.53 (*dd*, *J* = 2.1, 6.9 Hz, Me-18) (mixt rotamers).

16-*Methoxyisomatopensine* **12**. (CR red); UV $\lambda_{max}^{MeOH}$ nm: 217, 265, 315; IR $\nu_{max}^{CHCl_3}$ cm$^{-1}$: 1600, 1485, 1470, 1410, 1210, 1075, 750; EIMS *m/z* (rel. int.): 568(50), 540(15), 512(2), 470(5), 434(5), 308(30), 307(20), 291(10), 278(10), 277(10), 276(10), 180(5), 168(10), 167(30), 144(40), 130(15), 122(35), 121(35); $^1$H NMR (300 MHz, $CDCl_3$): 7.2–7.0 (*m*, 4H), 6.91 (*t*, *J* = 7 Hz, 1H), 6.66 (*t*, *J* = 7 Hz,

1H), 6.49 (*d*, $J = 7.8$ Hz, 2H), 5.58 (*dq*, $J = 1.4$, 6.9 Hz, 1H), 5.47 (*bq*, $J = 6.8$ Hz, 1H), 5.02 (*d*, $J = 1.5$ Hz, 1H), 4.736 (*s*, 1H), 4.568 (*s*, 1H), 4.01 (*d*, $J = 10.5$ Hz, 1H), 3.55 (*t*, $J = 3.2$ Hz, 1H), 3.082 (*s*, 3H), 2.81 (*ddd*, $J = 4$, 9.1, 12.8 Hz, 1H), 1.89 (*dd*, $J = 1.8$, 6.8 Hz, 3H), 1.86 (*dd*, $J = 1.3$, 6.9 Hz, 3H).

16-*Ethoxyisomatopensine* **13**. (CR red); $[\alpha]_D - 13°$ ($CHCl_3$; *c* = 0.3); UV $\lambda_{max}^{MeOH}$ nm: 216, 257, 293; IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 1600, 1480, 1465, 1400, 1285, 1275, 1210, 1060, 760; MS *m/z* (rel. int.): 614 $[M]^+$(1), 586(2), 568(100), 540(30), 512(5), 470(10), 434(10), 305(20), 277(30), 168(20), 158(30), 144(100), 130(60), 122(60), 121(60); $^1$H NMR (300 MHz, $CDCl_3$): 7.02 (*t*, $J = 8$ Hz, 1H), 6.79 (*t*, $J = 8$ Hz, 1H), 6.53 (*d*, $J = 8$ Hz, 1H), 6.46 (*d*, $J = 8$ Hz, 1H), 5.85 (*q*, $J = 7$ Hz, 1H), 5.75 (*q*, $J = 7$ Hz, 1H), 5.1 (*d*, $J = 1.5$ Hz, 1H), 4.86 (*s*, 1H), 4.72 (*s*, 1H), 4.37 (*t*, $J = 3$ Hz, 1H), 1.97 (*d*, $J = 7$ Hz, 1H), 1.95 (*d*, $J = 7$ Hz, 3H), 1.1 (*t*, $J = 7$ Hz, 3H); $^1$H NMR assignments according to COSY spectrum: 4.37 (H-3′), 4.1 (H-21′), 3.9 (2H-21), 3.85 (H-3), 3.85 (tryptamine $T_1$), 3.75 (H-21′ + $T_1$′), 3.5 ($OCH_2Me$), 3.35 ($T'_2$), 3.2 ($T_2$), 3.18 (H-15), 3.15 ($OCH_2Me$), 3.1 (H-15 + H-15′), 2.8 ($T'_3$), 2.65 ($T'_4$), 2.4 ($T_3$), 2.3 (H-14), 2.15 (H-16′), 2.1 (H-14 + $T_4$ + H-16), 2.0 (H-14′), 1.76 (H-14′).

18-*Hydroxymatopensine* **14**. (CR red); $[\alpha]_D + 68°$ (MeOH; *c* 0.3); UV $\lambda_{max}^{MeOH}$ nm: 218, 263, 313; IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 3350, 1600, 1485, 1455, 1390, 1310, 1275, 850; MS *m/z* (rel. int.): 586 $[M]^+$ (45), 569 (20), 568 (25), 555 (10), 307 (15), 305 (20), 293 (80), 279 (70), 277 (82), 228 (30), 180 (20), 165 (30), 164 (25), 144 (100), 130 (50), 122 (30) $^1$H NMR (300 MHz, $CDCl_3$) and assignments according to COSY spectrum: 7.2–7.05 (*m*, 4H), 6.7 (*t*, $J = 7.2$ Hz, 1H), 6.69 (*t*, $J = 7.2$ Hz, 1H), 6.32 (*d*, $J = 7.7$ Hz, 1H), 6.17 (*d*, $J = 7.5$ Hz, 1H), 5.53 (*t*, $J = 6.8$ Hz, H-19′), 5.35 (*q*, $J = 6.3$ Hz, H-19), 5.32 (*d*, $J = 2.1$ Hz, H-17), 5.28 (*d*, $J = 2$ Hz, H-17′), 4.32 (*m*, 2H-18′), 4.08 (*d*, $J = 5.5$ Hz, H-2), 4.07 (*d*, $J = 5.5$ Hz, H-2′), 3.52 (*br d*, $J = 14.5$ Hz, H-21), 3.2 (*d*, H-21′), 3.15 (H-3), 3.1 ($T_1$), 3.07 (H-21 + H-3′), 3.05 (H-21′ + $T'_1$), 3 (H-15 + H-15′), 2.95 ($T_2 + T'_2$), 2.85 ($T_3$), 2.6 ($T'_3$), 2.4 (H-14), 2.3 (H-14′), 2 ($T_4 + T'_4$), 1.9 (H-14), 1.8 (Me-18 + H-14′).

18,18′-*Bishydroxymatopensine* **15**. (CR red); UV $\lambda_{max}^{MeOH}$ nm: 215, 263, 310; IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 3300, 1600, 1480, 1455, 1390, 1310, 1270, 1070, 1050, 1000, 990; MS *m/z* (rel. int.): 602 (20), 584 (40), 571 (15), 555 (10), 296 (40), 295 (50), 293 (80), 279 (40), 277 (40), 211 (30), 184 (100), 156 (50), 144 (80), 130 (30); $^1$H NMR (300 MHz; $CDCl_3$): 6.8 (*t*, $J = 7$ Hz), 6.45 (*d*, $J = 7$ Hz, 1H), 5.7 (*br t*, $J = 7$ Hz, 1H), 5.5 (*br d*, 1H), 4.4 (*m*, 2H), 4.1 (*d*, $J = 5$ Hz, 1H).

*Bisnor-C-alkaloid D* **21**. (CR red); $[\alpha]_D = +71°$ ($CHCl_3$; *c* 0.8); UV $\lambda_{max}^{MeOH}$ nm: 217, 250, 297; IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 3300, 1740 (w), 1600, 1480, 1455, 1445, 1290, 1270, 1260, 1075, 1035, 830; MS *m/z* (rel. int.): 568 (0.1), 566 (0.1), 554 (2), 553 (2), 552 (5), 551 (2), 550 (3), 548 (1), 430 (2), 407 (4), 167 (10), 144 (15), 143 (30), 130 (50), 122 (20), 121 (30); $^1$H NMR and COSY assignments ($CDCl_3$, 300 MHz): 7–7.1 (*m*, 2H), 6.8 (*t*, $J = 8$ Hz, 1H), 6.5 (*d*, $J = 8$ Hz, 1H), 5.45 (*q*, $J = 7$ Hz, H-19), 4.95 (*s*, H-17), 4.55 (*s*, H-2), 3.4 (H-3), 3.2 ($T_1$ + H-21), 2.95 (H-15 + $T_2$ + H-21), 2.5 ($T_3$), 2.3 ($T_4$), 1.95 (H-14), 1.9 (H-14), 0.58 (*d*, $J = 7$ Hz, Me-18).

*Bisnor-C-curarine* **20**. $^1$H NMR and COSY assignments ($CDCl_3$, 300 MHz): 7.17 (*dt*, $J = 2$, 8 Hz, 1H), 7.15 (*br d*, $J = 8$ Hz, 1H), 6.92 (*br t*, $J = 8$ Hz, 1H), 6.74 (*d*, $J = 2$ Hz, H-17), 6.66 (*d*, $J = 8$ Hz, 1H), 5.45 (*q*, $J = 7$ Hz, H-19), 3.7 (*br s*, H-15), 3.39 (*br s*, 2H-21 + H-3), 3.21 (*m*, $T_1$), 2.91 (*ddd*, $J = 5$, 8, 12 Hz, T2), 2.65 (*ddd*, $J = 7$, 9, 16 Hz, $T_3$), 2.15 (*ddd*, $J = 2$, 4, 15 Hz, H-14), 2.0 (*m*, $T_4$), 1.8 (*d*, $J = 7$ Hz, Me-18), 1.78 (*m*, H-14).

*Longicaudatine Z* **25**. (CR yellow); $[\alpha]_D - 13°$ ($CHCl_3$; *c* 0.16); UV $\lambda_{max}^{MeOH}$ nm: 225, 255, 283, 291, 310 (sh); IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 3250, 2840, 2780, 2740, 1660 (w), 1605, 1480, 1460, 1275, 1215, 1150, 1100, 1055; MS *m/z* (rel. int.): 586 (1), 584 (2), 582 (1), 568 (2), 555 (15), 554 (45), 303 (20), 251 (50), 250 (100), 249 (45), 180 (15), 144 (70), 130 (35), 122 (70), 121 (50); $^1$H NMR and COSY assignments ($CDCl_3$, 300 MHz): 8.03 (*br s*, NH), 7.47 (*d*, $J = 8$ Hz, 1H), 6.8 (*t*, $J = 8$ Hz), 6.4 (*d*, $J = 8$ Hz, 1H), 5.95 (*d*, $J = 3$ Hz, H-17′), 5.55 (*q*, $J = 7$ Hz, H-19′), 5.53 (*q*, $J = 7$ Hz, H-19), 3.85 (*d*, $J = 12$ Hz, H-21), 3.8 (H-21′), 3.7 (H-3), 3.55 ($T_1$), 3.5 (H-2), 3.35 (H-21), 3.2 (H-21′), 3.15 ($T_2$), 3–3.1 ($T'_1 + T'_2$ + H-15′), 2.7 ($T'_3 + T'_4$ + H-14′ + H-15), 2.3 (H-14), 2.2 ($T_3$), 2 (H-14′), 1.9 ($T_4$ + H-14), 1.75 (Me-18), 1.65 (Me-18).

N-*Oxylongicaudatine* **26**. (CR blue); $[\alpha]_D + 156°$ ($CHCl_3$; *c* 0.59); UV $\lambda_{max}^{MeOH}$ nm: 225, 265, 285, 290, 308; IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 3250, 2840, 2800, 2740, 1640, 1600, 1480, 1460, 1285, 1260, 1235, 1105, 1025, 1005; MS *m/z* (rel. int.): 584 $[M]^+$ (4), 569 (40), 568 (100), 540 (10), 398 (15), 318 (30), 251 (25), 250 (50), 240 (40), 144 (20); $^1$H NMR ($CDCl_3 + CD_3OD$, 300 MHz): 9.1 (*br s*, N-H), 7.4 (*m*, 1H), 6.7 (*t*, $J = 8$ Hz, 1H), 6.37 (*t*, $J = 6$ Hz, H-19), 6.25 (*d*, $J = 8$ Hz, 1H), 6.02 (*s*, H-17′), 5.55 (*q*, $J = 7$ Hz, H-19′), 4.4 (*dd*, $J = 7$, 14 Hz, H-18), 1.45 (*d*, $J = 7$ Hz, Me-18′).

*Strychnofuranine* **17**. (CR yellow); $[\alpha]_D + 14°$ ($CHCl_3$, *c* 0.47); UV $\lambda_{max}^{MeOH}$ nm ($\log\varepsilon$) 221 (4.79), 275, 282 (4.12), 292 (3.99); IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 3400, 3350, 2850, 2800, 2740, 1450, 1370, 1330, 1320, 1210, 1155, 1115, 1100, 1005, 940, 920; MS *m/z* (rel. int.): 568 (20), 567 (10), 553 (1), 309 (5), 307 (7), 251 (30), 250 (100), 249 (50), 237 (25), 235 (25), 170 (15), 169 (20), 156 (20), 144 (15); $^1$H NMR ($CDCl_3$; 300 MHz), see above for COSY expt: 7.89 (*br s*, NH), 7.8 (*br s*, NH), 7.184 (*br s*, H-17), 6.043 (*br s*, H-17′), 5.61 (*q*, $J = 7$ Hz, H-19′), 5.48 (*q*, $J = 7$ Hz, H-19), 4.13 (*br d*, $J = 4.2$ Hz, H-15′), 3.6 (*m*, 2H-15 + H-3), 1.61 (*d*, $J = 6.5$ Hz, Me-18′), 1.27 (*d*, $J = 7.2$ Hz, Me-18).

$^1$H *NMR assignments for Wieland–Gumlich aldehyde* **1**. ($CDCl_3$; 300 MHz): 7.11 (*dt*, $J = 1$, 8 Hz, 1H), 7.07 (*br d*, $J = 8$ Hz, 1H), 6.84 (*dt*, $J = 1$, 8 Hz, 1H), 6.75 (*br d*, $J = 8$ Hz, 1H), 5.96 (*br t*, $J = 7$ Hz, H-19), 5.05 (*d*, $J = 1.5$ Hz, H-17), 4.26 (*dd*, $J = 7$, 14 Hz, H-18), 4.12 (*br s*, H-3), 3.98 (*dd*, $J = 6$, 14 Hz, H-18), 3.87 (*br d*, $J = 14$ Hz, H-21), 3.84 (*d*, $J = 10.5$ Hz, H-2), 3.46 (*m*, H-5), 2.95 (*m*, H-5), 2.86 (*d*, $J = 14$ Hz, H-21), 2.74 (*br s*, H-15), 2.35 (*dt*, $J = 14$, 4 Hz, H-14), 2.17 (*dd*, $J = 13$, 7 Hz, H-6), 1.88 (*dt*, $J = 14$, 1.5 Hz, H-14), 1.72 (*m*, H-6), 1.68 (*br d*, $J = 10.5$ Hz, H-16).

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